

Please type a plus sign (+) inside this box **[+]**

PTO/SB/05 (12/97)

Approved for use through 09/30/00. OMB 0651-0032

Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No. 03401.P084

Total Pages 3

First Named Inventor or Application Identifier Benjamin N. Eldridge, et al.

Express Mail Label No. EL 431 892 025 US

ADDRESS TO: **Assistant Commissioner for Patents**
Box Patent Application
Washington, D. C. 20231

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

1. X Fee Transmittal Form
(Submit an original, and a duplicate for fee processing)
2. X Specification (Total Pages 49)
(preferred arrangement set forth below)
 - Descriptive Title of the Invention
 - Cross References to Related Applications
 - Statement Regarding Fed sponsored R & D
 - Reference to Microfiche Appendix
 - Background of the Invention
 - Brief Summary of the Invention
 - Brief Description of the Drawings (if filed)
 - Detailed Description
 - Claims
 - Abstract of the Disclosure
3. X Drawings(s) (35 USC 113) (Total Sheets 11)
4. X Oath or Declaration (Total Pages 5)
 - a. X Newly Executed (Original or Copy)
 - b. Copy from a Prior Application (37 CFR 1.63(d))
(for Continuation/Divisional with Box 17 completed) (**Note Box 5 below**)
 - i. DELETIONS OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
5. Incorporation By Reference (useable if Box 4b is checked)
The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.
6. Microfiche Computer Program (Appendix)
7. Nucleotide and/or Amino Acid Sequence Submission
(if applicable, all necessary)
 - a. Computer Readable Copy
 - b. Paper Copy (identical to computer copy)
 - c. Statement verifying identity of above copies

[illegible]

17. If a **CONTINUING APPLICATION**, check appropriate box and supply the requisite information:
☐ Continuation ☐ Divisional ☐ Continuation-in-part (CIP)
of prior application No: _____

____ Customer Number or Bar Code Label

 (Insert Customer No. or Attach Bar Code Label here)

Country U.S.A. TELEPHONE (408) 720-8598 FAX (408) 720-9397

03401.P084

UNITED STATES PATENT APPLICATION
FOR
INTERCONNECT ASSEMBLIES AND METHODS

INVENTORS:

BENJAMIN N. ELDRIDGE
GAETAN MATHIEU

PREPARED BY:

BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN
12400 WILSHIRE BOULEVARD
SEVENTH FLOOR
LOS ANGELES, CA 90025-1026

(408) 720-8598

EXPRESS MAIL CERTIFICATE OF MAILING

"Express Mail" mailing label number: EL 431 892 025 US

Date of Deposit: July 30, 1999

I hereby certify that I am causing this paper or fee to be deposited with the United States Postal Service
"Express Mail Post Office to Addressee" service on the date indicated above and that this paper or fee has
been addressed to the Assistant Commissioner for Patents, Washington, D. C. 20231

Connie Thayer
(Typed or printed name of person mailing paper or fee)

Connie Thayer
(Signature of person mailing paper or fee)

7-30-99
(Date signed)

INTERCONNECT ASSEMBLIES AND METHODS

FIELD OF THE INVENTION

5 The present invention relates to interconnect assemblies and methods for making and using interconnections and methods for making these interconnect assemblies.

BACKGROUND OF THE INVENTION

10 There are numerous interconnect assemblies and methods for making and using these assemblies in the prior art. Interconnect assemblies for making electrical interconnections with semiconductor integrated circuits must support the close spacing between interconnect elements, sometimes referred to as the pitch of the interconnect elements. Certain interconnect assemblies perform their functions through testing and
15 the useful life of the integrated circuit. One type of interconnect assembly in the prior art uses a resilient contact element, such as a spring, to form either a temporary or a permanent connection to a contact pad on a semiconductor integrated circuit. Examples of such resilient contact elements are described in U.S. Patent 5,476,211 and also in co-pending, commonly-assigned, U.S. Patent Application entitled
20 "Lithographically Defined Microelectronic Contact Structures," Serial No. 09/032,473, filed February 26, 1998, and also co-pending, commonly-assigned, U.S. Patent Application entitled "Interconnect Assemblies and Methods," Serial No. 09/114,586, filed July 13, 1998. These interconnect assemblies use resilient contact elements which can resiliently flex from a first position to a second position in which

the resilient contact element is applying a force against another contact terminal. The force tends to assure a good electrical contact, and thus the resilient contact element tends to provide good electrical contact.

These resilient contact elements are typically elongate metal structures which in
5 one embodiment are formed according to a process described in U.S. Patent
5,476,211. In another embodiment, they are formed lithographically (e.g. in the
manner described in the above-noted patent application entitled "Lithographically
Defined Microelectronic Contact Structures"). **Figure 1A** illustrates an example of
resilient contact elements which are formed using a technique described in U.S. Patent
10 5,476,211. **Figure 1B** shows an example of a resilient contact element which is
formed using lithographic techniques such as those described in the above-noted U.S.
Patent Application entitled "Lithographically Defined Microelectronic Contact
Structures." In general, resilient contact elements are useful on any number of
substrates such as semiconductor integrated circuits, probe cards, interposers, and
15 other electrical assemblies. For example, the base of a resilient contact element may
be mounted to a contact terminal on an integrated circuit or it may be mounted onto a
contact terminal of an interposer substrate or onto a probe card substrate or other
substrates having electrical contact terminals or pads. The free end of each resilient
contact element can be positioned against a contact pad on another substrate to make
20 an electrical contact through a pressure connection when the one substrate having the
resilient contact element is pressed towards and against the other substrate having a
contact element which contacts the free end of the resilient contact element.

It will be appreciated that in certain instances, it may be desirable to secure the free end to the corresponding contact element by an operation such as soldering.

However, in many instances, it is appropriate to allow the contact to be made by pressure between the two substrates such that the contact end of the resilient contact element remains free.

The resilient contact elements are useful for making electrical contacts because their resilience maintains pressure for good electrical contact and because they allow for tolerance in the vertical or Z direction such that all contact elements will be able to make a contact even if their heights vary slightly. However, this pressure sometimes

leads to the deformation or degradation of resilient contact elements as they are compressed too much in the vertical direction. One approach to prevent the deformation or degradation of such resilient contact elements is to use a stop structure on one or both of the two substrates. The stop structure effectively defines the maximum deflection of the resilient contact element such that each of the resilient contact elements is prevented from overflexing (undue deflection) or being destroyed as a result of the two substrates being pressed toward each other. **Figure 1A** shows an example of an integrated circuit having contact pads 103 and having, for each of the contact pads, a resilient contact element 110 mounted thereto. A plurality of stop structures 104 and 105 are disposed on the surface of the integrated circuit 102.

These stop structures will prevent undue deflection and may engage another substrate which is pressed towards the surface of the semiconductor integrated circuit 102.

Figure 1B shows an example of a lithographically defined resilient contact element on a substrate, such as a semiconductor integrated circuit 120. The integrated circuit includes on its surface a stop structure 150.

The lithographically defined resilient contact structure of **Figure 1B** includes
5 an intermediate layer 123 which makes an electrical interconnection with the pad 122 through an opening in the passivation layer 121 on the surface of the substrate of the integrated circuit 120. A first metal layer 125 and a second metal layer 126 are then formed to create a beam having a step 128 and a beam portion 127. In this example, the beam portion is substantially parallel to the surface of the substrate 120. A tip
10 structure including components 181, 182, 183, 184, and 185 is then subsequently mounted to the end of the beam 127 to create a resilient contact structure. Further details concerning methods for creating and using such lithographically defined resilient contact structures are described in the co-pending U.S. Patent Application entitled "Lithographically Defined Microelectronic Contact Structures" which is
15 referred to above and which is hereby incorporated herein by reference. While this lithographically defined resilient contact element provides the advantage that it can be formed lithographically using modern photolithographic techniques which are prevalent in the semiconductor industry, there are certain disadvantages with this type of resilient contact element. For example, when a force F as shown in **Figure 1B** is
20 applied downwardly against the tip 185, a torqueing action occurs at the base of the resilient contact element. This torqueing action results from the pressure contact which occurs when a contact element on another substrate is pressed towards the tip 185. This torque at the base tends to place stress at the base and along the beam

portion. If the beam portion 127 is a rectangular shape, this results in the stress being localized at the portion of the beam which is next to the base of the resilient contact element. While the stop structure 150 provides some assurance that certain levels of stress will not be exceeded, there are still certain concentrated areas of stress, as a

5 result of the rectangular shape, which must be accounted for when designing a resilient contact element. Typically, accounting for these concentrated areas of stress requires increasing the use of the amount of materials at certain points in the resilient contact element. This in turn may limit the ability to design resilient contact elements to be smaller. This is particularly undesirable as the sizes of structures on

10 semiconductor integrated circuits are being reduced over time.

Thus, it is desirable to provide an improved resilient contact element.

SUMMARY OF THE INVENTION

The present invention provides an interconnect assembly and methods for making and using the assembly. In one example of the present invention, an interconnect assembly includes a substrate and a contact element disposed on the substrate. A first portion of the contact element is adapted to be free-standing and is further adapted to be capable of moving from a first position to a second position when a force is applied to the first portion of the contact element. The interconnect assembly further includes a stop structure which is disposed on a second portion of the contact element. The stop structure defines in part the second position of the contact element. In one particular exemplary embodiment of the present invention, the substrate comprises a semiconductor integrated circuit. Force is applied when another contact element is brought into mechanical and electrical contact with the contact element. The stop structure defines the second position which defines a maximum flexing of the contact element.

According to another example of the present invention, an interconnect assembly is formed by a method of disposing a contact element on a substrate, where a first portion of the contact element is free-standing and is capable of moving from a first position to a second position when a force is applied to the first portion of the contact element. The method also includes disposing a stop structure on a second portion of the contact element, where the stop structure defines the second position.

It will be appreciated that a plurality of contact elements of the invention may be used to create an interconnect assembly.

An example of a method according to another aspect of the present invention involves the formation of a freestanding elongate resilient contact element using a mold. In this method, a mold is depressed into a deformable material; the mold determines a shape of at least a portion of the freestanding elongate resilient contact element. This portion of the freestanding elongate resilient contact element is then formed on the deformable material.

Various other assemblies and methods are described below in conjunction with the following figures.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is illustrated by way of example and not limitation in the figures of the accompanying drawings in which like references indicate similar elements.

5 **Figure 1A** shows an example of a plurality of resilient contact elements disposed on a substrate with stop structures on that substrate. **Figure 1A** is a perspective view of the substrate 102 with its resilient contact elements and stop structures.

10 **Figure 1B** shows an example of a lithographically formed resilient contact element formed on a substrate with a stop structure. **Figure 1B** is a cross-sectional view of the resilient contact element and the stop structure.

Figure 2A is a cross-sectional view of a resilient contact element according to one embodiment of the present invention.

15 **Figure 2B** is a cross-sectional view of another embodiment of a resilient contact structure of the present invention with a stop structure disposed over a base of the resilient contact element.

Figure 2C shows a cross-sectional view of another example of an embodiment of a resilient contact element according to the present invention in which a stop structure is disposed over a base of the resilient contact element.

20 **Figure 2D** shows a cross-sectional view of another example of a resilient contact element of the present invention.

Figures 2E, 2F, 2G, and 2H show cross-sectional views which compare the deflection of an initially straight resilient contact element, shown in **Figure 2E**, to the deflection of an initially curved resilient contact element shown in **Figure 2G**.

Figure 3A is a top view of one example of a resilient contact element according to the present invention. **Figure 3B** is a top view of another example of a resilient contact element according to the present invention. **Figure 3C** is a top view of another example of a resilient contact element according to the present invention. **Figure 3D** shows, in top view, an array of resilient contact elements disposed on a substrate.

Figure 4 shows, in cross-sectional view, an example of an interconnect assembly of the present invention which includes a resilient contact element having a stop structure disposed over the base of the contact element and **Figure 4** also shows another substrate being brought into contact with the substrate carrying the stop structures and the resilient contact element.

Figure 5 is a flowchart showing an example of a method for forming a resilient contact element and a stop structure according to one embodiment of the present invention.

Figure 6A shows a cross-sectional view of the structure of an interconnect assembly during the formation of a resilient contact element according to one method of the present invention.

Figure 6B shows another cross-sectional view at a later processing stage in the fabrication process which produces a resilient contact element according to one embodiment of the present invention.

Figure 6C shows a top view of a portion of the structure 608 shown in **Figure 6B**.

Figure 6D shows a cross-sectional view of the structure which results after several processing steps shown in **Figure 5**.

5 **Figure 6E** shows a cross-sectional view of an alternative substrate onto which a resilient contact element of the present invention may be formed.

Figure 6F shows a cross-sectional view after certain processing steps in the method of **Figure 5**.

10 **Figure 6G** shows another cross-sectional view after further processing steps of the method of **Figure 5**.

Figure 6H shows a top view of a portion of the structure shown in **Figure 6G**.

Figure 6I shows another cross-sectional view of the structure being formed according to the method shown in **Figure 5**.

15 **Figure 6J** shows another cross-sectional view of a resilient contact element as it is being formed according to the method shown in **Figure 5**.

Figure 6K shows a further cross-sectional view after further processing steps according to the method of **Figure 5**.

20 **Figure 6L** shows a top view according to one embodiment of the structure shown in **Figure 6K**.

Figure 7A shows in cross-sectional view an embodiment with multiple resilient contact elements and their corresponding stop structures.

Figure 7B shows a perspective view of one resilient contact element disposed within a well formed by the contact structure according to one exemplary embodiment of the present invention.

Figure 8A shows an alternative embodiment in cross-sectional view of a
5 resilient contact element according to the present invention.

Figure 8B shows in perspective view the resilient contact element of **Figure 8A** after the element has been assembled.

Figures 9A, 9B, 9C and 9D show cross-sectional views of a substrate during another method, according to the invention, for forming a resilient contact
10 element.

DETAILED DESCRIPTION

The present invention relates to interconnection assemblies and methods and particularly to interconnect assemblies and methods for making mechanical and electrical connection to contact elements on an integrated circuit. The following

5 description and drawings are illustrative of the invention and are not to be construed as limiting the invention. Numerous specific details are described to provide a thorough understanding of the present invention. However, in other instances, well known or conventional details are not described in order to not unnecessarily obscure the present invention in detail.

10 **Figure 2A** shows a cross-sectional view of a resilient contact element which is one example of an embodiment of the present invention. The resilient contact element 201 of **Figure 2A** includes a first metal layer 209 and a second metal layer 210 which have been formed at an oblique angle relative to the surface of the substrate 202. The first metal layer 209 may be selected for its resiliency properties in order to

15 impart resiliency to the resilient contact element and the second metal layer 210 may be selected for its electrical conductivity properties in order to provide good electrical conductivity for the resilient contact element. The substrate 202 is typically a semiconductor substrate which includes an integrated circuit which includes various terminals, one of which is shown as the contact pad 207 in **Figure 2A**.

20 Representative terminals carry input/output signals, power or ground. This contact pad 207 is coupled through a wiring layer 206 to internal circuitry within the integrated circuit. The wiring layer 206 is disposed within an insulating layer 204, and layers 206 and/or 204 may be covered by a passivating layer 205 on the top

surface of the substrate 202. The layer 203 may be an insulating layer or a polysilicon layer or other layers which are known and used in integrated circuits. The contact pad 207 is electrically and mechanically coupled to a shorting layer 208 which is disposed above the contact pad 207. The metal layers 209 and 210 are formed above the shorting layer 208 with a base portion of each of the metal layers 209 and 210 above and electrically connected to contact pad 207. Electrical conductivity between the contact pad 207 occurs through the shorting layer 208 and the metal layer 209 and finally to the metal layer 210. It will be appreciated that the resilient contact element 201 of **Figure 2A** may also be used for other types of interconnect assemblies such as probe card assemblies or interposers or other connection systems where a resilient contact element may provide electrical conductivity from a conductor in the substrate 202 to the tip, which is free-standing, of the resilient contact element 201. As can be seen from **Figure 2A**, this resilient contact element is both free-standing and elongate. Also, the resilient contact element, in the embodiment shown in **Figure 2A**, is sloped relative to the surface of the substrate 202. In a preferred embodiment, this slope typically forms an oblique angle relative to the surface of the substrate 202.

In one particular embodiment of the present invention, the resilient contact element 201 may be formed such that the beam portion which extends from the base has a substantially triangular shape. This is shown in the top view of the resilient contact structure 301 shown in **Figure 3A**. That is, the beam portion 215 of the resilient contact element 201 may be formed in such a way as to have a substantially triangular shape such as the beam portion 303 of the resilient contact element 301 shown in **Figure 3A**. The resilient contact element 301 includes a base 302 which is

attached to the beam portion and a tip 304 which makes electrical contact with another interconnect terminal/pad. **Figure 3B** shows, in a top view, another example of a resilient contact element 301A which has a beam portion 303A which has a substantially triangular shape. The beam portion 303A is attached to the base 302A and includes a tip 304A.

Figure 2B shows another embodiment of the present invention in which a stop structure 211 is disposed on the top surface of the substrate 202 and is also disposed on top of a portion of the base 214 of the resilient contact element 212. In this embodiment shown in **Figure 2B**, the substrate 202 includes the similar components 203, 204, 205, 206, 207, 208, 209 and 210 as in the case of the interconnect assembly shown in **Figure 2A**. A resilient contact element 212 includes two metal layers 209 and 210 which have been formed such that a base portion 214 of both metal layers rests on the upper surface of the shorting layer 208 while beam portion 215 extends from an end of the base portion 214 at an oblique angle relative to the surface of the substrate 202. The beam portion of the resilient contact element 212 may have a triangular shape or other shapes such as rectangular shapes or other shapes which are known to be used for resilient contact elements. In one embodiment, however, it is preferred that the beam 215 have a triangular shape such as the beam 303 of **Figure 3A** or beam 303A of **Figure 3B**. The stop structure 211 is formed over the base portion 214 of the resilient contact element 212. The stop structure 211 acts to prevent overflexing (e.g. undue deflection) of the resilient contact element by determining the maximum amount of deflection of the resilient contact element 212 as it is pressed by a force F towards the surface of the substrate 202.

When another contact element, such as a contact pad on another substrate, is pressed toward and against the tip 216 of the resilient contact element 212, the upper surface of the stop structure 211 will engage a corresponding surface of the other substrate to prevent the substrate from being pressed further towards the surface of the substrate

5 202. That is, the travel between the two substrates is limited by the stop structure 211 such that the stop structure 211 will define or determine a minimum distance between the substrates and hence a maximum flexing of the resilient contact element 212.

Further details in connection with advantages of and uses of stop structures are described in co-pending U.S. Patent Application Serial No. 09/032,473, which was
10 filed July 13, 1998 and is entitled "Interconnect Assemblies and Methods;" this co-pending patent application entitled "Interconnect Assemblies and Methods" is hereby incorporated herein by reference.

Figure 2C shows a simplified example of a resilient contact structure with a stop structure according to one exemplary embodiment of the invention. The
15 interconnect assembly 231 includes a substrate 232 which has a wiring layer 237 embedded therein. The wiring layer 237 is electrically coupled to a base portion 235 of a resilient contact element 234. The base portion 235 is coupled to the beam portion 236. Typically, as described below, the beam portion 236 and the base portion 235 are formed integrally in one operation. Both the base portion 235 and the
20 beam portion 236 may contain multiple conductive layers such as the layers 208, 209, and 210 as shown in **Figures 2A** and **2B**. As in the case of the embodiments shown in **Figures 2A** and **2B**, the beam portion 236 of the resilient contact element 234 extends from an end of the base portion 235 at an oblique angle relative to the

surface of the substrate 232. The stop structure 233 is disposed above and adhered to the surface of the substrate 232 and it is also disposed above and adhered to the top surface of the base portion 235. As shown in **Figure 2C**, an end of the wiring layer 237 is mechanically adhered to and electrically coupled to the base portion 235. Since the stop structure 233 is mechanically adhered to the top surface of the substrate 232 and to the top surface of the base portion 235, any torque created at the base portion 235 (e.g. as a result of a force exerted against the tip of the beam portion 236 when a contact pad, such as the contact pad 411 shown in **Figure 4**, is pressed towards the surface of the substrate 232) will be balanced through various parts of the entire structure, including the stop structure 233, rather than merely the base portion 235 and the beam portion 236. It will be appreciated that, in an alternative embodiment, a stop structure may be disposed on only the base portion 235 and not the substrate 232 and that this stop structure will tend to balance any torque created at the base portion.

Several dimensions are labeled in **Figure 2C** and also **Figure 3A** in order to provide examples of the present invention. It will be appreciated that the following examples are merely illustrative of the invention and are not intended to limit the invention and are not intended to provide an exhaustive set of examples for possible structures which are within the scope of the present invention. The distance c represents in one example (e.g. see **Figure 4**) the maximum displacement or deflection of the resilient contact element. In one example, this is approximately 75 microns (about 3 mils). This distance c is normally less than the element's compliance which is the total amount of deflection or flexing which is available before "failure" of the resilient contact element. This distance in one example (e.g. see **Figure 4**)

represents the travel of the tip from a point where there is no force pressing against the tip to the point where the tip has been pressed flush with the top surface of the stop structure 233. Examples of these two states are shown in **Figure 2C** where no force is being applied to the tip and **Figure 4** where a force has been applied to the tip such that one substrate 410 has its surface virtually in contact with the top surface of the stop structures 406 and 407.

The thickness t represents the total thickness of the resilient contact element in a perpendicular cross-section of the resilient contact element as shown in **Figure 2C**. Typically, this thickness will be approximately the same throughout any particular cross-section, although it will be appreciated that in alternative embodiments, this thickness may be different at certain cross-sections. It will also be appreciated that **Figure 2C** represents a simplified example of a resilient contact element 234 and that the base and the beam portions may be fabricated from one or more conductive layers. In a typical embodiment, the thickness is approximately 25 microns, and the total height h of the resilient contact element 234 is approximately 150 microns (about 6 mils).

For certain embodiments, the spring rate of the resilient contact element may be approximately 1 to 2 grams per mil, where the spring rate "k" represents the force of the spring divided by the displacement of the spring ($k = F/x$). It will be appreciated that once the geometry and the materials have been selected for a particular resilient contact element, the thickness of the spring generally determines the spring rate. Thickness is a major factor in determining the stress at a maximum deflection, which is also dependent upon the material in the resilient contact element. It will be

appreciated that certain design points or goals will be established for a resilient contact element such that the maximum possible stress for the resilient contact element is less than a desired amount. The use of the stop structure 233 will tend to control the maximum amount of stress and also tend to relieve the stress at maximum deflection by counteracting the torque at the base portion of the resilient contact element. This can be seen from **Figure 4** which will be further described below.

The resilient contact element may have a curved shape which provides certain advantages that are described here in conjunction with **Figures 2D, 2E, 2F, 2G and 2H**. **Figure 2D** shows a cross-sectional view of a curved resilient contact element 234A which includes a base portion 235A, a tip 239A and a curved beam portion 236A. The base portion 235A is coupled electrically to the wiring layer 237. The curvature of the beam portion may be used to compensate for bending of the beam portion during deflection of the resilient contact element. This compensation is shown in the comparison shown by **Figures 2E, 2F, 2G and 2H**.

A stop structure 233 is disposed on the base portion 235A and (optionally) on the substrate 232.

Figures 2E and 2F respectively show an initially straight resilient contact element before and after deflection of the resilient contact element. When a force F is applied to the tip of the beam portion 236, the beam portion curves as shown in **Figure 2F**, and this causes the tip to be tilted away from the surface of the contact point on the other substrate and causes a shallow angle θ_1 to be formed between a line representing the surface of the contact point and a line through the end of the beam portion. These lines are shown in **Figure 2F** along with the angle θ . The

shallowness of this angle tends to be undesirable for making a good electrical connection.

Figures 2G and 2H respectively show an initially curved resilient contact element before and after deflection of the resilient contact element. When the force F is applied to the tip of the beam portion 236A, this beam portion tends to be straightened out as shown in **Figure 2H**. As a result of this straightening out, the angle θ_2 (the angle between the line representing the surface of the contact point and a line through the end of the beam portion) is not as shallow as angle θ_1 and thus better electrical contact may be accomplished using the curved resilient contact element.

Figure 3A and Figure 3B show another aspect of the present invention in which the beam portion of the resilient contact element has a substantially triangular shape. The resilient contact element 301 includes a base 302 which corresponds to the base 235 in **Figure 2C**. The beam portion 303 shown in the top view of **Figure 3A** corresponds to the beam portion 236 of **Figure 2C**. The beam portion 303 includes a tip 304 which corresponds to the tip 239 of the resilient contact element 234 of **Figure 2C**. The triangular shape of the beam portion 303 tends to more evenly distribute across (e.g. tip to base) the entire beam the stress created when the tip 304 is pressed towards the surface on which the base 302 is resting. This allows the use of less material in the beam 303 while still obtaining good performance for the resilient contact element, such as the ability to withstand continued stress throughout the useful life of the resilient contact element. **Figure 3B** shows an alternative triangular shaped resilient contact element.

Figure 3C shows, in top view, another example of a resilient contact element 310 which has a substantially triangular shape. In this case, the triangle is modified at the electrical contact end 312 to include a portion of a rectangle. The beam portion of the resilient contact element 310 is normally free-standing and capable of deflections
5 when depressed and includes a triangular part 314 and a rectangular part 312. The triangular part is attached to the base portion 316. The beam portion may be attached to the base portion 316 at an oblique angle and may be lithographically formed together with the base portion 316. It can be seen that the cross-sectional areas taken at different cross-sections 318 and 320 will be different, and this is also true of the
10 contact elements 301 and 301A.

The geometry of the beam portions of these substantially triangular shaped resilient contact elements provides improved performance over a cantilever beam spring which has a substantially constant cross-sectional area. Other shapes may also be selected to provide improved performance relative to cantilever beam springs which
15 have substantially constant cross-sectional areas. The substantially triangular shape gives better behavior of the spring under stress and allows for tighter packing (small pitches) for the springs. **Figure 3D** shows an array of tightly packed (e.g. pitch of 10 microns) resilient contact elements 310A, 310B, 310C and 310D of the type shown in **Figure 3C** on a substrate 322 (which may be an integrated circuit or an
20 electrical connection substrate which may be used to test or make permanent contact to an integrated circuit). The geometry of the beam portion is selected to give optimum stress behavior for a given size constraint (e.g. the size as determined by the packing of the contact elements) and a given spring rate and a given/desired amount of

compliance for the contact element. A smaller size, as determined by a size constraint, for a given spring rate and given compliance tends to place greater stress at certain points of a cantilever beam having a constant cross-sectional area. A substantially triangular shaped resilient contact element, on the other hand, allows for tighter packing (see, e.g. **Figure 3D**) and smaller sizes while, for the same spring rate and given compliance, allowing better behavior under stress.

In a typical embodiment, the dimensions l_1 and l_2 are about 9 mils while the dimension l_3 is about 27 mils. An array of these resilient contact elements may be formed on a substrate, such as an integrated circuit or a contactor for making contact to an integrated circuit, to create a densely packed array of such resilient contact elements. **Figure 8B** shows one example of a layout of an array on a substrate 803. In one embodiment, these resilient contact elements may be packed so densely that the distance between corresponding points (e.g. bases) on adjacent contact elements is less than 30 mils and even as small as 0.1 mils (approximately 2.5 microns). **Figure 3D** shows another example of an array of densely packed (tight pitch) resilient contact elements.

The actual use of an interconnect assembly according to one embodiment of the present invention will now be described while referring to **Figure 4**. The substrate 402 includes a resilient contact element 403 having a beam portion 405 and a base portion 404. In this particular embodiment, the beam portion 405 may have a triangular shape or may have another shape such as a rectangular shape. Two stop structures 406 and 407 are adhered to the upper surface of the substrate 402 and the stop structure 406 is also adhered to the top portion of the base 404. The base 404

makes mechanical and electrical contact with the wiring layer 415 in the substrate 402. It will be appreciated that the substrate 402 may be a semiconductor integrated circuit or may be a passive wiring layer such as a probe card or interposer structure. Another interconnection assembly 410 having a contact pad 411 is brought into electrical and mechanical contact with the tip of the beam portion 405 as shown in **Figure 4**. The entire assembly 401, which includes substrates 410 and 402, is pressed together to assure a good pressure connection between the tip of the beam portion 405 and the surface of the contact pad 411. The contact pad 411 makes electrical contact with other components through the wiring layer 412 of the substrate 410. As the substrate 410 is pressed towards the substrate 402, the tip of the beam portion 405 makes a wiping action which occurs laterally along the direction of the arrow 413 as shown in **Figure 4**. This improves the electrical contact between the beam portion 405 and the pad 411, thus improving the electrical contact between the wiring layers 415 and 412. It will be appreciated that **Figure 4** illustrates the circumstance where the substrate 410 is pressed completely against the substrate 402 and thus no further "travel" is possible (they cannot get closer). This represents the maximum deflection of the resilient contact element 403. However, in use of the assembly 401, the two substrates may not be abutting such that the resilient contact element 403 is deflected less than the maximum deflection while still achieving acceptable electrical conductivity between the beam 405 and the pad 411. The final assembly of substrates 402 and 410 may be held in place by various techniques (with either maximum deflection of the resilient contact elements or less than maximum deflection) including

by mechanical forces (e.g. F_m shown in **Figure 4**) and/or by an adhesive applied between the surface of substrates 402 and 410 (not shown).

A method of fabricating an interconnect assembly will now be described; this method represents one particular example of the present invention and it will be appreciated that various other methods may be employed using alternative techniques and procedures. The method 500 shown in **Figure 5** begins with the operation 502. This particular method assumes that a redistribution layer will be applied in order to redistribute contact pads having a certain arrangement and geometry to a set of another contact pads having a different arrangement and/or geometry. It will be appreciated that in other circumstances, a redistribution layer may not be necessary, and the contact elements of the invention may terminate directly on the wiring layers of the substrate without a redistribution layer; see **Figure 6E**. In operation 502, a passivation layer, such as a polyimide layer, is applied to the upper surface of the substrate having a contact pad disposed on the upper surface. In one embodiment, a polyimide layer may be spun onto the upper surface to uniformly cover the surface. Then the passivation layer is patterned using conventional photolithography to create openings in the passivation layer over the contact pads at the surface of the substrate. These contact pads may be input/output interconnections in a semiconductor integrated circuit or they may be contact terminals on a passive or active board or substrate such as a probe card or an interposer or other interconnect assemblies.

Figure 6A shows an example of an interconnect assembly 601 having a contact 604 at the upper surface of the substrate 602. A wiring layer 603 is disposed in the substrate 602 in order to provide electrical conductivity between the pad 604 and

another component, such as a circuit within the substrate 602 or a contact terminal at another location on the substrate 602. It will be appreciated that typically the wiring layer 603 is disposed within an insulating layer in the substrate 602. It will also be appreciated that the portion shown in **Figure 6A** is the upper portion of the substrate 602 and that other wiring layers and/or circuitry is disposed below this portion shown in **Figure 6A**. The passivation layer applied in operation 402 is shown as passivation layer 605 in **Figure 6A**. This passivation layer has been patterned to create an opening 606 over the contact pad 604.

In operation 504 of **Figure 5**, a shorting layer is applied over the surface of the passivating layer 605 and over the surface of the contact pad 604. Then, a conventional photoresist is applied over the entire surface of the shorting layer and this photoresist is patterned using conventional photolithography to create an opening over the shorting layer. The shorting layer may be formed from copper, titanium, or titanium/tungsten or other appropriate metallization and may be sputtered onto the surface of layer 605. An example of a resulting interconnect assembly after operation 504 is shown in **Figure 6B**. The interconnect assembly 608 of **Figure 6B** includes a shorting layer 609 which is disposed above the passivation layer 605 and the contact pad 604. The contact pad and the shorting layer 609 are in electrical conductivity. The patterned photoresist layer 610 includes an opening 611 over a portion of the shorting layer. This opening will be used to create a redistribution layer wherein the layout of the contact pad 604 will be redistributed to another location. This may be done to relax the interconnection pitch achieved at the end of the process when the resilient contact elements have been formed on the substrate 602. **Figure 6C** shows

a top view of the redistribution wiring layer. In particular, **Figure 6C** shows the pattern in the photoresist layer 610 which has created a hole in the patterned photoresist 610. This hole exposes a portion of the shorting layer 609 as shown in **Figure 6C**.

5 In operation 506 of **Figure 5**, a redistribution layer is applied over the shorting layer. This redistribution layer may be applied by electrolytically plating (or electroless plating) a metal layer (e.g. copper or gold) onto the exposed portion of the shorting layer, where the shorting layer is used as the cathode in an electrolytic plating operation. It will be appreciated that on a typical substrate there will be many such
10 redistribution traces created on the surface of the substrate in each of the patterned openings in the patterned photoresist 610.

 After the redistribution layer has been applied, the patterned photoresist layer 610 is removed and the shorting layer which is exposed after removing the patterned photoresist layer is also removed. The redistribution layer may be used as a mask to
15 remove the shorting layer. Thus, in this case, typically one metal (e.g. Ti/W) will be used to create a shorting layer and another metal (e.g. Cu) will be used to create the redistribution layer such that the redistribution layer will remain intact while the shorting layer is etched away or removed under the action of a solvent or etching agent which is resisted by the redistribution layer metal. The result of operation 506 is
20 shown in **Figure 6D**. It can be seen that the patterned photoresist layer 610 has been removed and that the unprotected portion of the shorting layer 609 has also been removed, leaving the structure of the interconnect assembly 614 shown in **Figure 6D**. In an alternative embodiment in which the shorting layer 609 is required for

subsequent electrolytic plating (e.g. because layer 642 has electrically isolated regions due to openings in the layer), then the shorting layer 609 is not removed in operation 506 but is removed in operation 514.

It will be appreciated that operations 502, 504, and 506 have been used to
5 create a plurality of redistribution traces, such as a redistribution layer, on the surface of the substrate 602. This may be required in certain cases where the contact pads were designed to be connected to an interconnect mechanism other than a resilient contact element or it may be desirable for other reasons. It will also be appreciated that in certain instances, no such redistribution layer is necessary and thus a resilient
10 contact element may be fabricated on a via or other contact element on the surface of a substrate. An example of a via is shown in **Figure 6E** in which a post 623 of conductive material is exposed at the upper surface 622 of the substrate 621. This conductive post 623 is electrically coupled to the wiring layer 623 which is also in the substrate 621. Typically, the material encasing the wiring layer 624 and the post 623
15 is an insulating layer. The substrate 621 will typically be a part of a semiconductor integrated circuit although other interconnect assemblies may also be used, such as printed wiring substrates, interposers, etc. The processing from the structure 620 shown in **Figure 6E** is similar to the processing of the structure 614 shown in **Figure 6D** from steps 508 through 516 of **Figure 5**. That is, while the structure
20 620 does not need to be processed in operations 502, 504, and 506, it may be processed with operations 508, 510, 512, 514, and 516 as will structure 614 shown in **Figure 6D**.

The next operation in the method 500 is operation 508 in which a photoresist is applied and patterned to include an opening which has a slope on the photoresist. The resulting structure of the interconnect assembly is shown as structure 631 in **Figure 6F**. The photoresist 633 has been applied and patterned to create an opening 632 which has a slope 634 on a portion of the opening. The opening is disposed at least partially over a portion of the conductive layer 615. It will be appreciated that typically, the flat portion of this opening will be utilized to construct a base for the resilient contact element while the sloped portion 634 will be used to construct the beam portion of the resilient contact element.

There are numerous techniques known in the art for creating openings in photoresist which include a slope on the photoresist. For example, a gray-scale mask having a relatively continuous gradient of opacity from clear to black may be used to create a slope on the photoresist. Other methods may be used to provide the tapered side wall, which include: gently reflowing the masking material to taper a side of the opening; controlling the light exposure intensity or time to the masking material; during exposure, varying the distance of the mask from the masking layer; exposing the masking layer two or more times, one through the mask having a small transparent area and separately with a mask having a larger transparent area; or combinations of these methods. Methods for forming an opening having a tapered side wall are further described in co-pending U.S. Patent Application entitled "Lithographically Defined Microelectronic Contact Structures" which has been referred to above and which is hereby incorporated herein by reference. Also described below is a method in which a

mold is used to stamp a slope in a deformable material which is then used to form a resilient contact element.

After operation 508, the operation 510 involves applying a seed layer and then applying and patterning a photoresist layer to create a triangular opening (in one exemplary embodiment) for a resilient contact element. The seed layer 642 shown in **Figure 6G** may be applied by conventionally sputtering an appropriate metallic layer (e.g. Cu or Ti or Ti/W) onto the surface of the photoresist 633. If the shorting layer 609 was removed in operation 506, then the seed layer 642 should provide a continuous conductive surface except for the side wall 645, but if the shorting layer 609 was retained in operation 506, then the seed layer 642 may be electrically discontinuous over its entire surface.

In one preferred implementation, care is taken in the sputtering operation to avoid or prevent the sputtered material from remaining on the vertical side wall 645 so the opening in the photoresist 633 does not receive a continuous layer of the seed material. In another implementation, sputtering does cover some or all of the vertical side wall 645. In this implementation, it is generally preferable that the subsequent masking and patterning step cover some or all of the sputtered side wall so as to minimize or prevent subsequent deposition of additional conductive materials on the vertical side wall.

After the seed layer 642 is applied, a photoresist layer is applied over the surface of the seed layer 642 as shown in **Figure 6G**. This photoresist layer is then patterned to create an opening 643 in the patterned photoresist layer 646 as shown in **Figure 6G**. This opening will be used to deposit at least one conductive layer, such

as a metal layer, on the top of the exposed portion of the seed layer 642. This will include the deposition of a beam portion of the resilient element on the sloping portion 644 of the exposed portion of the seed layer 642. It is generally desirable for the subsequent plating or other deposition operation to fill the final shape contours in a regular manner. In one preferred embodiment, a seed layer is deposited so as to be primarily at the bottom of an opening in photoresist, particularly where the photoresist is from the masking and patterning phase of operation 510.

Figure 6G shows an example of a structure 641 after completion of the operation 510. **Figure 6H** shows a top view of a portion of the structure 641. In particular, the portion of the structure 641 over the opening 643 is shown in the top view of **Figure 6H**. It can be seen that the patterned photoresist layer 646 exposes only a portion of the seed layer 642. In the particular example shown in **Figure 6H**, the base portion of the resilient contact element will be formed in the rectangular portion of the exposed seed layer 642 and the beam portion of the resilient contact element will be formed in the triangular portion of the exposed seed layer 642. This will result in a resilient contact structure having a beam portion which is substantially triangular in shape, such as the resilient contact structure shown in **Figure 3A**. It will be appreciated that in other embodiments, other shapes, such as rectangular shapes, may be used for the beam portion and thus top views of such structures would look differently than **Figure 6H**.

After structure 641 has been created by completing the operation 510, operation 512 is performed on the structure 641 to achieve the structure 651 shown in **Figure 6I**. Operation 512 typically involves in one exemplary embodiment the

electrolytic plating of a first metal layer and then a second metal layer into the triangular opening. In alternative embodiments, the opening may be a different shape (e.g. a rectangular shape to create a rectangular beam portion) and alternative methods may be employed to deposit one or more conductive layers into the opening. The seed
5 layer 642 (or a retained underlying shorting layer if the seed layer 642 is electrically discontinuous over its surface) will be used as the cathode in the electrolytic plating operation to plate the metal layers 652 and 653 onto the exposed portion of the shorting layer in the opening 643 as shown in **Figure 6I**. In one embodiment, the first metal layer 652 is selected to provide sufficient mechanical resiliency so that the
10 final resilient contact element has sufficient resiliency for its intended operation. In one particular embodiment, a nickel cobalt alloy may be used. This alloy may be 70% nickel and 30% cobalt. This alloy may be heat treated as described in co-pending Application Serial Number 08/931,923 filed September 17, 1997. The second metal layer 653 is typically selected to provide good electrical conductivity; for example
15 gold, or rhodium or a palladium cobalt alloy may be used. The composition of the various other layers and materials will be described further below. It will also be appreciated that numerous other types of materials may be selected for these metal layers, and these materials have been described in U.S. Patent 5,476,211.

After one or more conductive layers have been deposited into the opening 643
20 and the structure 651 has been completed, then operation 514 is performed to remove the photoresist layers and the sputtered shorting layers to achieve the structure 661 shown in **Figure 6J**. Conventional solvents or dry etching methods for removing or stripping the photoresist layers are utilized and solvents or etchants which will

selectively remove the sputtered seed layer, such as seed layer 642, are used to remove the shorting layer. Thus, the patterned photoresist layer 646 and the patterned photoresist layer 636 is removed. Also, almost all of the seed layer 642 is removed except for the portion of the layer under the base of the resilient contact element 662 as shown in **Figure 6J**. This results in the structure shown in **Figure 6J** which then may be used as an interconnect assembly (without a travel stop structure) or may be used with a travel stop structure after such structure has been created in operation 516.

If it is desired to create a stop structure for the interconnect assembly, then step 516 is performed on the structure 661. This operation involves the application of a photo-imageable material (PIM), such as a negative photoresist such as SU8 which is commercially available, over the entire surface of the structure 661. It is desirable that this PIM be applied uniformly to a uniform thickness and relatively flat, preferably as flat as possible. Thus it is preferred to spin the PIM, such as a photoresist, onto the surface of the structure 661. Care should be taken to apply enough photoresist material such that after it is spun on, it covers the base of the resilient contact element 662. That is, the height of the final structure created by this spun-on photoresist should be more than the height h of the base of the resilient contact element.

Typically, the height of the final structure should also be less than the height of the freestanding contact point of the resilient contact element. Typically, the difference between the height of the freestanding contact point and the height of the final stop structure created by this photoresist should be fabricated to be the maximum deflection amount c described above.

After the proper amount of photoresist has been applied to achieve the desired height of the photoresist relative to the height h of the base of the resilient contact element (elements), then the photoresist layer is exposed and developed. The photoresist layer is exposed through a mask 690 such that an area around and below the beam portion of the resilient contact element remains unexposed while adjacent regions become exposed. Because the PIM in one embodiment is a negative photoresist, this will mean that the area which did not receive an exposure due to the mask 690 will be developed to remove the photoresist (and the exposed portions of the photoresist will remain), creating the opening 674 as shown in **Figure 6K**. In one embodiment, this mask 690 may be a rectangular mask which provides sufficient clearance for the beam portion to move up and down in the opening 674. In an alternative embodiment, the mask 690 may be a triangular mask which is designed to fit around the triangular shape of the beam portion of the resilient contact element when the resilient contact element has a triangular beam shape. Thus, the structure 671 shown in **Figure 6K** results from operation 516 and produces a stop structure 672 which is adhered to the passivation layer 605 and to the conductive layer 615 and to the base portions 652A and 653A of the resilient contact structure. Note that a portion 673 of the stop structure 672 is adhered to and is over the base portions 653A and 652A.

Figure 6L shows a top view of the structure shown in **Figure 6K**. **Figure 6L** assumes that the mask 690 had a triangular shape rather than a rectangular shape. Thus, the opening in the patterned photoresist 672 which forms the stop structure is a triangular opening which matches the shape of the triangular beam portion while

providing sufficient clearance for the beam portion to move up and down within the opening 674. The base 653a is shown underlying the travel stop structure 672 in **Figure 6L**. In an alternative embodiment, a rectangular mask 690a may be used over the beam portion in the exposure operation 516 to create a rectangular opening 674a shown in **Figure 7B**. This rectangular opening in the stop structure 672 may be used either for a triangular beam portion as shown in **Figure 7B** or may be used for a beam portion which is rectangular. It will be appreciated that whichever mask geometry is selected, it should provide sufficient clearance for the beam portion to move up and down within the opening in the stop structure 672.

10 **Figure 7A** shows a cross-sectional view of a plurality of resilient contact elements which include stop structures surrounding and disposed on the bases of the resilient contact elements.

15 **Figure 8A** shows an alternative embodiment for creating a resilient contact element which includes three portions, a base portion, a beam portion, and a contact portion. The contact portion is useful for contacting a second electronic component as described above in detail. In addition, the contact portion may be used to attach a tip structure onto the end of the beam. Examples of various tip structures and methods for mounting tip structures are described in the co-pending U.S. Patent Application entitled "Lithographically Defined Microelectronic Contact Structures" and also in co-
20 pending U.S. Patent Application 08/819,464, which was filed March 17, 1997. In particular, **Figure 8A** shows the structure after a stage in the fabrication process of an interconnection assembly after operation 512 (without operations 502, 504, and 506 because this assembly does not utilize a redistribution layer). The structure of

Figure 8A includes a conductive post 604a disposed in an insulating layer of the substrate 602a. The conductive post is electrically coupled to a seed layer 642a which corresponds to the seed layer 642 of **Figure 6I**. The seed layer 642a has been sputtered over a patterned photoresist layer 633a which includes an opening having a sloped side wall. The sputtered seed layer 642a is used to electrolytically plate two metal layers to create the structure shown in **Figure 8A**. The electroplating operation occurs through the patterned photoresist mask 646a which corresponds to the patterned mask 646 of **Figure 6I**. After the plating operation has occurred, each metal layer includes a base portion, such as the base portion 653a, a beam portion, such as the beam portion 653b, and a contact portion, such as the contact portion 653c. After the electroplating operation is completed, operation 514 may be performed to remove the photoresist layers 646a and 633a and then the sputtered seed layer 642a may be removed except for the portion under the base 653a. The resulting structure may be used as a resilient contact element in an interconnect assembly without a stop structure or the stop structure may be formed by performing operation 516 as described above.

Figure 8B illustrates an array 800 of two resilient contact elements 801 and 802 on the surface of the substrate 803. **Figure 8B** is a perspective view and it will be appreciated that typically a large number of resilient contact elements may be disposed on the surface of the substrate, such as a semiconductor integrated circuit or other interconnect assemblies. The resilient contact elements shown in **Figure 8B** are similar to the type shown in **Figure 8A** in that they include a contact portion at the end of the beam structure. The beam structure, such as beam portion 653B, may

be a substantially triangular shape which is attached to the base portion 653A. The contact portion 653C may serve itself as the contact tip for making contact to another contact terminal (e.g. contact terminal 411 as shown in **Figure 4**) or a tip structure as described above may be mounted onto the foot portion 653C to provide a tip structure.

- 5 This structure may also be adapted for permanent connection to the contact pad (e.g. by use of solder or conductive epoxy).

Figures 9A, 9B, 9C and 9D illustrate another method for forming a resilient contact element according to the present invention. A mold 901, which may be photolithographically formed, includes a "negative" image of at least a portion of a resilient contact element. The mold 901 is shown in **Figure 9A** prior to being used on the deformable material 903 and is positioned above the deformable material 903, which is disposed on a substrate 905 which includes wiring layer 906. The substrate 905 and wiring layer 906 is similar to the structure shown in **Figure 6E**. The deformable material 903 may be any number of materials, such as PMMA (poly methyl methacrylate), which are deformable when pressed with a mold or stamp and which can be used to receive the deposition of spring metals to form a resilient contact element and can be subsequently removed. The mold 901 includes, in the embodiment shown in **Figure 9A**, a base portion 901B and a sloped portion 901A. It will be appreciated that other geometries may be used, including a rotated "L" shape (e.g. \neg) or a shape that will generate the curved beam portion of **Figure 2D**.

10
15
20

The mold 901 is pressed into the deformable material as shown in **Figure 9B**. Several pounds of pressure may be necessary (depending on the type of deformable material) in order to deform the deformable material to achieve the desired

shape. This in one exemplary embodiment causes the base portion 901B to be nearly touching the surface of substrate 905, leaving a thin region of the deformable material separating this surface from the base portion 901B. The mold 901 forces the deformable material to take the positive of its negative shape as shown in **Figure 9B**.

5 The mold 901 is then separated from the substrate 905 and deformable material 903, leaving the structure shown in **Figure 9C**. This structure is then "cleaned" to remove the thin region 903A of the deformable material which was under the base portion 901B. The structure may be cleaned with an isotopic etch which removes all exposed deformable material but does not effect the substrate 905. This etch is
10 performed for a sufficient duration to remove all of the thin region 903A while leaving most of the remainder of the deformable material 903, including the sloped portion 903B. The structure may be cleaned to remove the thin region 903A with a plasma etch or a reactive ion etch or with a laser ablation etch. After removal of the thin region 903A, the structure is shown in **Figure 9D**, and it is ready for further
15 processing (e.g. operations 510, 512, 514, and 516 of **Figure 5**) to create a resilient contact element using the molded deformable material.

There are numerous ways to create the mold. The mold may be formed from a silicon wafer by laser etching the surface of the wafer. A glass backing substrate with a photo-imageable material (which can be hardened) may be used with a mask to
20 photolithographically define the mold. A silicon carbide wafer may be machined to define the mold by using electro-discharge machining techniques on the silicon carbide wafer. A negative of the mold may be formed in wax (e.g. paraffin), then sputtering a

shorting layer on the surface of the negative, after which the mold is formed by electrolytically plating a metal onto the shorting layer on the wax.

The foregoing discussion has provided certain details with respect to materials and process steps. It will be appreciated that the present invention may be practiced
5 with other types of materials and process variations. For example, in just some of many preferred implementations, the sputtered shorting layers may use copper, gold, aluminum, titanium, titanium/tungsten or other appropriate metallization. Further, the redistribution trace 615 may use copper or gold material in creating the trace. Other
10 materials may be employed to achieve similar results as will be appreciated by those skilled in the art. As another alternative embodiment, it will be appreciated that other methods for forming various layers may be employed. For example, processes based on electroless plating, chemical vapor deposition (CVD), or phase vapor deposition (PVD) may be utilized rather than electrolytic plating.

In the foregoing specification, the present invention has been described with
15 reference to specific exemplary embodiments thereof. It will, however, be evident that various modifications and changes may be made thereto without departing from the broader scope and spirit of the invention as set forth in the appended claims.

CLAIMS

What is claimed is:

- 1 1. An interconnect assembly comprising:
2 a substrate;
3 a contact element disposed on said substrate, a first portion of said contact
4 element adapted to be free-standing and further adapted to be capable
5 of moving from a first position to a second position when a force is
6 applied to said first portion of said contact element; and
7 a stop structure disposed on a second portion of said contact element, said stop
8 structure defining said second position.
- 1 2. The interconnect assembly as in claim 1, wherein a plurality of said contact
2 elements are disposed on said substrate, said contact elements disposed in a pitch
3 having a range of about 2.5 microns to 2000 microns.
- 1 3. The interconnect assembly as in claim 1, wherein said substrate has a bond
2 pad connected to a microelectronic device, said contact element disposed on said bond
3 pad.
- 1 4. The interconnect assembly as in claim 1, wherein said substrate has a re-
2 distributed conductor connected to a microelectronic device, said contact element
3 disposed on said re-distributed conductor.

1 5. The interconnect assembly as in claim 1, wherein said substrate has a bond
2 pad connected to a test equipment, said contact element disposed on said bond pad.

1 6. The interconnect assembly as in claim 1, wherein said contact element is
2 resilient and wherein said stop structure presses against said second portion with said
3 force when said force is applied to said first portion.

1 7. The interconnect assembly as in claim 1, wherein said contact element
2 comprises at least one metal layer.

1 8. The interconnect assembly as in claim 1, wherein said contact element
2 comprises a first metal layer and a second metal layer, said first metal layer providing
3 said contact element with resiliency and said second metal layer providing electrical
4 conductivity for said contact element.

1 9. The interconnect assembly as in claim 1, wherein said contact element is an
2 elongate resilient contact element.

1 10. The interconnect assembly as in claim 1, wherein said first portion of said
2 contact element is sloped relative to a surface of said substrate such that one end of
3 said first portion of said contact element is at a height above said surface of said
4 substrate.

1 11. The interconnect assembly as in claim 1, wherein a portion of said first portion
2 of said contact element protrudes at a height from a surface of said stop structure.

1 12. The interconnect assembly as in claim 11, wherein said height in which said
2 contact element protrudes from said surface of said stop structure is a predetermined
3 height.

1 13. The interconnect assembly as in claim 1, wherein said substrate comprises an
2 integrated circuit in a semiconductor material, and wherein said force is applied when
3 another contact element is brought into mechanical and electrical contact with said
4 contact element.

1 14. The interconnect assembly as in claim 1, wherein said contact element is a
2 resilient contact element and wherein said force is applied when another contact
3 element is brought into mechanical and electrical contact with said contact element and
4 wherein said force causes said resilient contact element to flex from said first position
5 to said second position and wherein said stop structure defines said second position
6 which defines a maximum flexing of said resilient contact element.

1 15. The interconnect assembly as in claim 1, wherein said first portion of said
2 contact element has substantially a triangular shape and a third portion of said contact
3 element being a point of said triangular shape.

SCANNED

1 16. The interconnect assembly as in claim 1, wherein said stop structure has a
2 vertical height that is less than a vertical height of a shortest contact element that is
3 statistically likely to exist.

1 17. A method of forming an interconnect assembly, said method comprising:
2 disposing a contact element on a substrate, a first portion of said contact
3 element being free-standing and being capable of moving from a first
4 position to a second position when a force is applied to said first
5 portion of said contact element; and
6 disposing a stop structure on a second portion of said contact element, said
7 stop structure defining said second position.

1 18. The method as in claim 17, wherein disposing said contact element on said
2 substrate includes disposing another contact element on said substrate in a fine pitch.

1 19. The method as in claim 17, wherein said contact element is free-standing and
2 resilient.

1 20. The method as in claim 17, wherein disposing said contact element further
2 comprises:
3 applying a first masking layer on said substrate;

4 forming in said first masking layer, an opening extending into said first
5 masking layer, said opening having a tapered wall; and
6 depositing a metal layer on said tapered wall of said opening of said first
7 masking layer.

1 21. The method as in claim 20, wherein said tapered wall is tapered using at least
2 one technique of tapering by using a gradual scale, tapering by reflowing, tapering by
3 controlled exposure, tapering by varying a mask distance or tapering by multiple
4 exposures.

1 22. The method as in claim 20, wherein after forming said tapered wall, the
2 method further comprises:
3 placing a mask pattern over said first masking layer, said mask pattern having
4 a pattern substantially triangular in shape; and
5 depositing said metal layer in said opening of said first masking layer in said
6 substantially triangular shape according to said mask pattern.

1 23. The method as in claim 20, wherein depositing said metal layer includes using
2 one of a sputtering deposition process, an electroplating process, a chemical vapor
3 deposition process and an electroless plating process.

1 24. The method as in claim 20, wherein depositing said metal layer includes:

2 depositing a first metal layer, said first metal layer selected for its resilient
3 property; and
4 depositing a second metal layer, said second metal layer selected for its
5 electrical conducting property.

1 25. The method as in claim 20, further comprising:
2 removing a portion of said first masking layer as to allow said contact element
3 to be free-standing; and
4 applying an additional layer as to cover said second portion of said contact
5 element.

1 26. The method as in claim 25, further comprising:
2 planarizing said first masking layer to form said stop structure, said stop
3 structure having a vertical height less than a vertical height of a shortest
4 contact element that exists.

1 27. The method as in claim 20, further comprising:
2 removing said first masking layer;
3 applying a second layer over said second portion of said contact element and
4 allowing said first portion of said contact element to be free-standing.

1 28. The method as in claim 27, further comprising:

2 planarizing said second layer to form said stop structure, said stop structure
3 having a vertical height less than a vertical height of a shortest contact
4 element.

1 29. The method as in claim 17, wherein said contact element is a resilient contact
2 element which is free-standing and wherein said force is applied when another contact
3 element is brought into mechanical and electrical contact with said contact element and
4 wherein said force causes said resilient contact element to flex from said first position
5 to said second position and wherein said stop structure defines said second position
6 which defines a maximum flexing of said resilient contact element.

1 30. The method as in claim 17, wherein said contact element is a resilient contact
2 element which is free-standing and wherein said stop structure presses against said
3 second portion with said force when said force is applied to said first portion and
4 wherein said force is applied when another contact element is brought into mechanical
5 and electrical contact with said contact element.

1 31. An electrical system comprising:
2 a first substrate having a first contact element;
3 a second substrate;
4 at least one second contact element disposed on said second substrate, a first
5 portion of said second contact element adapted to be free-standing and
6 further adapted to be capable of moving from a first position to a

7 second position when a force is applied to said first portion of said
8 second contact element by said first contact element; and
9 a stop structure disposed on a second portion of said second contact element,
10 said stop structure defining said second position.

1 32. The electrical system as in claim 31, wherein said second substrate has a bond
2 pad connected to a microelectronic device, said second portion of said second contact
3 element disposed on said bond pad, and said first substrate is one of (1) a test probe
4 assembly having said first contact element to make contact with said second contact
5 element and (2) a package having said first contact element to house said
6 microelectronic device during use of said microelectronic device.

1 33. A method for forming a freestanding, elongate resilient contact element, said
2 method comprising:
3 depressing a mold into a deformable material, said mold determining a shape
4 of at least a portion of said freestanding, elongate resilient contact
5 element;
6 forming at least said portion of said freestanding, elongate resilient contact
7 element on said deformable material.

1 34. A method as in claim 33 wherein said forming comprises depositing a
2 conductive material on said deformable material after said deformable material has
3 been deformed with said mold.

1 35. A method as in claim 34 wherein said mold comprises a plurality of shapes for
2 a corresponding plurality of portions of freestanding, elongate resilient contact
3 elements.

1 36. A method as in claim 35 further comprising:
2 removing said deformable material after depositing said conductive material.

1 37. A method as in claim 36 wherein said freestanding, elongate resilient elements
2 are disposed on corresponding electrical interconnect pads on a substrate.

1 38. A method as in claim 37 wherein said substrate comprises a semiconductor
2 integrated circuit.

1 39. A lithographically formed resilient contact element having a curved beam
2 portion which extends upwardly from a substrate and which is lithographically
3 defined.

1 40. A lithographically formed resilient contact element as in claim 39 further
2 comprising:
3 a base portion attached mechanically to said substrate and electrically coupled
4 to an electrical interconnection terminal on said substrate, and wherein

5 said resilient contact element is freestanding when released after being
6 initially formed.

1 41. A lithographically defined resilient contact element as in claim 40 wherein a
2 curve of said curved beam portion extends upwardly away from said substrate and
3 said curve is lithographically defined by a curved slope in a sacrificial layer which is
4 removed to release said resilient contact element.

1 42. A lithographically defined resilient contact element as in claim 40 further
2 comprising a sacrificial layer which defines a curve of said curved beam portion.

ABSTRACT OF THE DISCLOSURE

Interconnect assemblies having resilient contact elements and methods for making these assemblies. In one aspect, the interconnect assembly includes a substrate and a resilient electrical contact element disposed on the substrate. A first
5 portion of the resilient contact structure is disposed on the substrate and a second portion extends away from the substrate and is capable of moving from a first position to a second position under the application of a force. A stop structure is disposed on the surface of the substrate and on a surface of the first portion of the resilient contact structure. According to another aspect of the present invention, a beam portion of the
10 resilient contact structure has a substantially triangular shape.

2
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467
468
469
470
471
472
473
474
475
476
477
478
479
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735
736
737
738
739
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000
1001
1002
1003
1004
1005
1006
1007
1008
1009
1010
1011
1012
1013
1014
1015
1016
1017
1018
1019
1020
1021
1022
1023
1024
1025
1026
1027
1028
1029
1030
1031
1032
1033
1034
1035
1036
1037
1038
1039
1040
1041
1042
1043
1044
1045
1046
1047
1048
1049
1050
1051
1052
1053
1054
1055
1056
1057
1058
1059
1060
1061
1062
1063
1064
1065
1066
1067
1068
1069
1070
1071
1072
1073
1074
1075
1076
1077
1078
1079
1080
1081
1082
1083
1084
1085
1086
1087
1088
1089
1090
1091
1092
1093
1094
1095
1096
1097
1098
1099
1100
1101
1102
1103
1104
1105
1106
1107
1108
1109
1110
1111
1112
1113
1114
1115
1116
1117
1118
1119
1120
1121
1122
1123
1124
1125
1126
1127
1128
1129
1130
1131
1132
1133
1134
1135
1136
1137
1138
1139
1140
1141
1142
1143
1144
1145
1146
1147
1148
1149
1150
1151
1152
1153
1154
1155
1156
1157
1158
1159
1160
1161
1162
1163
1164
1165
1166
1167
1168
1169
1170
1171
1172
1173
1174
1175
1176
1177
1178
1179
1180
1181
1182
1183
1184
1185
1186
1187
1188
1189
1190
1191
1192
1193
1194
1195
1196
1197
1198
1199
1200
1201
1202
1203
1204
1205
1206
1207
1208
1209
1210
1211
1212
1213
1214
1215
1216
1217
1218
1219
1220
1221
1222
1223
1224
1225
1226
1227
1228
1229
1230
1231
1232
1233
1234
1235
1236
1237
1238
1239
1240
1241
1242
1243
1244
1245
1246
1247
1248
1249
1250
1251
1252
1253
1254
1255
1256
1257
1258
1259
1260
1261
1262
1263
1264
1265
1266
1267
1268
1269
1270
1271
1272
1273
1274
1275
1276
1277
1278
1279
1280
1281
1282
1283
1284
1285
1286
1287
1288
1289
1290
1291
1292
1293
1294
1295
1296
1297
1298
1299
1300
1301
1302
1303
1304
1305
1306
1307
1308
1309
1310
1311
1312
1313
1314
1315
1316
1317
1318
1319
1320
1321
1322
1323
1324
1325
1326
1327
1328
1329
1330
1331
1332
1333
1334
1335
1336
1337
1338
1339
1340
1341
1342
1343
1344
1345
1346
1347
1348
1349
1350
1351
1352
1353
1354
1355
1356
1357
1358
1359
1360
1361
1362
1363
1364
1365
1366
1367
1368
1369
1370
1371
1372
1373
1374
1375
1376
1377
1378
1379
1380
1381
1382
1383
1384
1385
1386
1387
1388
1389
1390
1391
1392
1393
1394
1395
1396
1397
1398
1399
1400
1401
1402
1403
1404
1405
1406
1407
1408
1409
1410
1411
1412
1413
1414
1415
1416
1417
1418
1419
1420
1421
1422
1423
1424
1425
1426
1427
1428
1429
1430
1431
1432
1433
1434
1435
1436
1437
1438
1439
1440
1441
1442
1443
1444
1445
1446
1447
1448
1449
1450
1451
1452
1453
1454
1455
1456
1457
1458
1459
1460
1461
1462
1463
1464
1465
1466
1467
1468
1469
1470
1471
1472
1473
1474
1475
1476
1477
1478
1479
1480
1481
1482
1483
1484
1485
1486
1487
1488
1489
1490
1491
1492
1493
1494
1495
1496
1497
1498
1499
1500
1501
1502
1503
1504
1505
1506
1507
1508
1509
1510
1511
1512
1513
1514
1515
1516
1517
1518
1519
1520
1521
1522
1523
1524
1525
1526
1527
1528
1529
1530
1531
1532
1533
1534
1535
1536
1537
1538
1539
1540
1541
1542
1543
1544
1545
1546
1547
1548
1549
1550
1551
1552
1553
1554
1555
1556
1557
1558
1559
1560
1561
1562
1563
1564
1565
1566
1567
1568
1569
1570
1571
1572
1573
1574
1575
1576
1577
1578
1579
1580
1581
1582
1583
1584
1585
1586
1587
1588
1589
1590
1591
1592
1593
1594
1595
1596
1597
1598
1599
1600
1601
1602
1603
1604
1605
1606
1607
1608
1609
1610
1611
1612
1613
1614
1615
1616
1617
1618
1619
1620
1621
1622
1623
1624
1625
1626
1627
1628
1629
1630
1631
1632
1633
1634
1635
1636
1637
1638
1639
1640
1641
1642
1643
1644
1645
1646
1647
1648
1649
1650
1651
1652
1653
1654
1655
1656
1657
1658
1659
1660
1661
1662
1663
1664
1665
1666
1667
1668
1669
1670
1671
1672
1673
1674
1675
1676
1677
1678
1679
1680
1681
1682
1683
1684
1685
1686
1687
1688
1689
1690
1691
1692
1693
1694
1695
1696
1697
1698
1699
1700
1701
1702
1703
1704
1705
1706
1707
1708
1709
1710
1711
1712
1713
1714
1715
1716
1717
1718
1719
1720
1721
1722
1723
1724
1725
1726
1727
1728
1729
1730
1731
1732
1733
1734
1735
1736
1737
1738
1739
1740
1741
1742
1743
1744
1745
1746
1747
1748
1749
1750
1751
1752
1753
1754
1755
1756
1757
1758
1759
1760
1761
1762
1763
1764
1765
1766
1767
1768
1769
1770
1771
1772
1773
1774
1775
1776
1777
1778
1779
1780
1781
1782
1783
1784
1785
1786
1787
1788
1789
1790
1791
1792
1793
1794
1795
1796
1797
1798
1799
1800
1801
1802
1803
1804
1805
1806
1807
1808
1809
1810
1811
1812
1813
1814
1815
1816
1817
1818
1819
1820
1821
1822
1823
1824
1825
1826
1827
1828
1829
1830
1831
1832
1833
1834
1835
1836
1837
1838
1839
1840
1841
1842
1843
1844
1845
1846
1847
1848
1849
1850
1851
1852
1853
1854
1855
1856
1857
1858
1859
1860
1861
1862
1863
1864
1865
1866
1867
1868
1869
1870
1871
1872
1873
1874
1875
1876
1877
1878
1879
1880
1881
1882
1883
1884
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
1911
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
2039
2040
2041
2042
2043
2044
2045
2046
2047
2048
2049
2050
2051
2052
2053
2054
2055
2056
2057
2058
2059
2060
2061
2062
2063
2064
2065
2066
2067
2068
2069
2070
2071
2072
2073
2074
2075
2076
2077
2078
2079
2080
2081
2082
2083
2084
2085
2086
2087
2088
2089
2090
2091
2092
2093
2094
2095
2096
2097
2098
2099
2100
2101
2102
2103
2104
2105
2106
2107
2108
2109
2110
2111
2112
2113
2114
2115
2116
2117
2118
2119
2120
2121
2122
2123
2124
2125
2126
2127
2128
2129
2130
2131
2132
2133
2134
2135
2136
2137
2138
2139
2140
2141
2142
2143
2144
2145
2146
2147
2148
2149
2150
2151
2152
2153
2154
2155
2156
2157
2158
2159
2160
2161
2162
2163
2164
2165
2166
2167
2168
2169
2170
2171
2172
2173
2174
2175
2176
2177
2178
2179
2180
2181
2182
2183
2184
2185
2186
2187
2188
2189
2190
2191
2192
2193
2194
2195
2196
2197
2198
2199
2200
2201
2202
2

Figure 1A

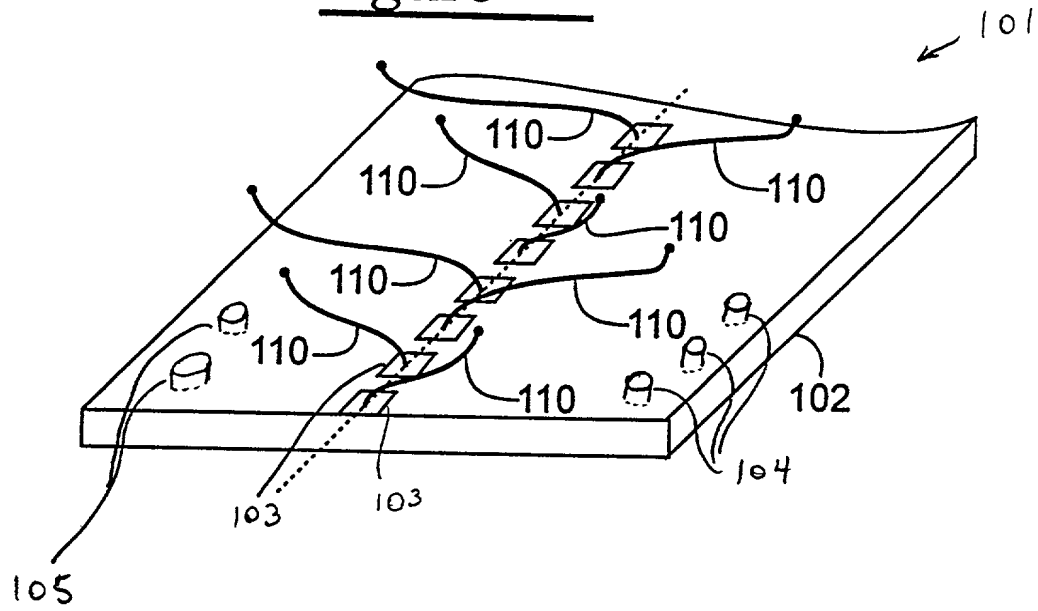


Figure 1B

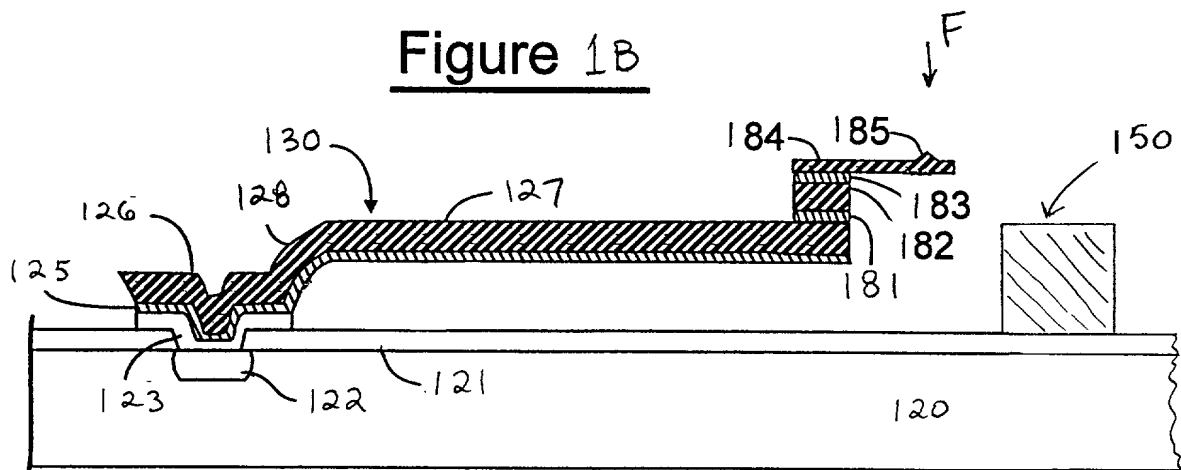


FIG. 2A

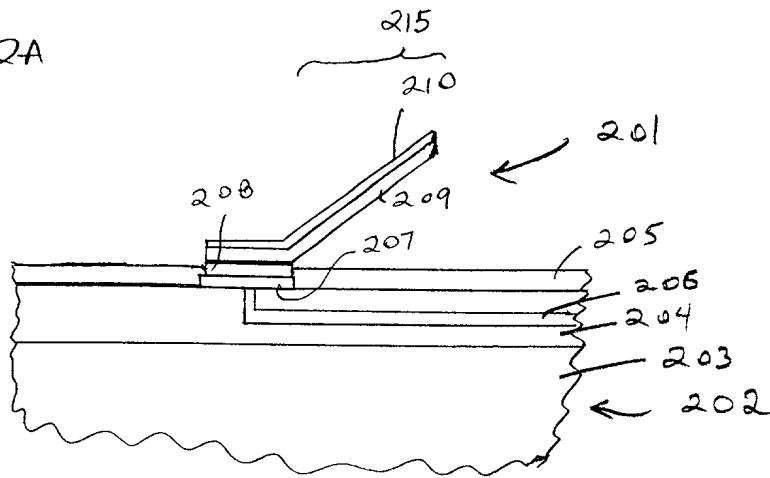


Fig. 2B

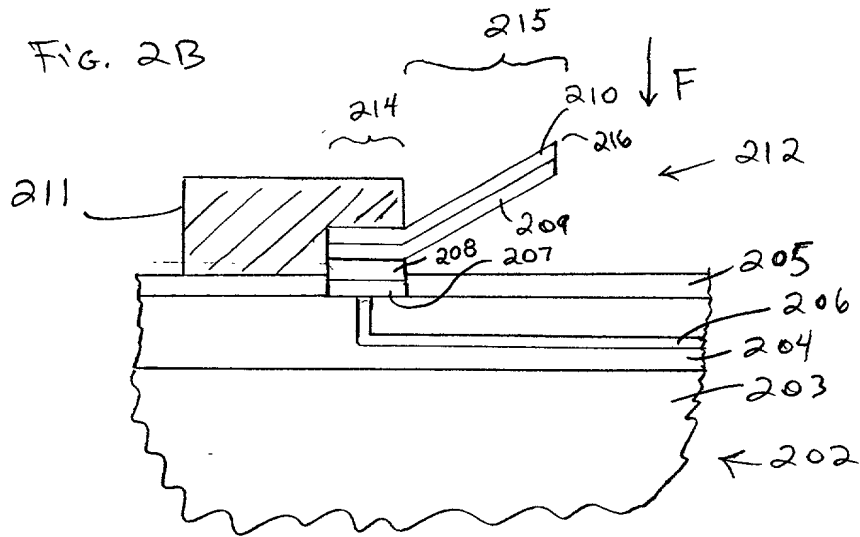


Fig. 2C

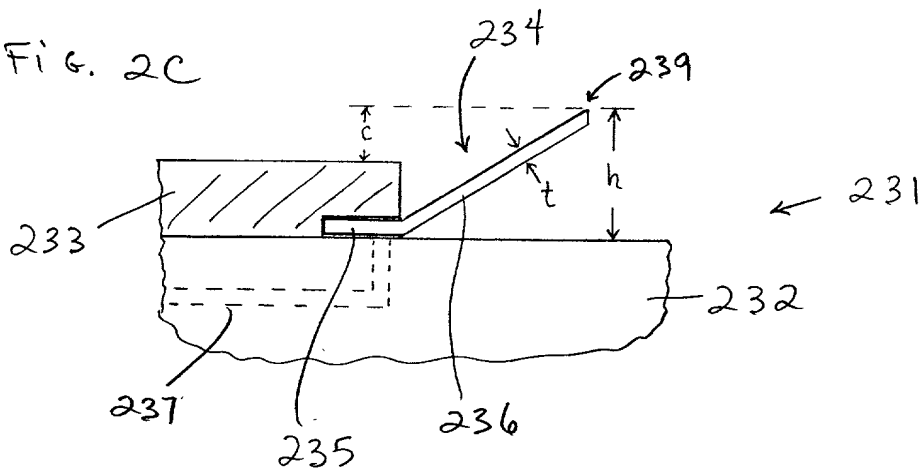


FIG. 2D is a cross-sectional view of a device 200 in a second embodiment. The device 200 includes a substrate 232. A layer 233 is formed on the substrate 232. A curved layer 234A is formed on the layer 233. A component 235A is formed on the layer 233, having a height 'c'. A curved layer 236A is formed on the layer 233, having a height 'h'. A dashed line indicates a cross-section 237.

Diagram illustrating a second embodiment of the device. It shows a base 235 and a tilted member 236.

FIG. 2F

236

F

θ

235

A diagram of a bent beam. A horizontal line represents the ground. A beam segment, labeled 235A, lies on the ground. Another segment, labeled 236A, is bent upwards at an angle θ_1 relative to the horizontal. A downward force F is applied to the end of segment 236A. A dashed line extends from the horizontal ground level, and the angle between this extension and segment 236A is labeled θ_2 . The text $\theta_2 > \theta_1$ is written next to the diagram.



FIG. 3A

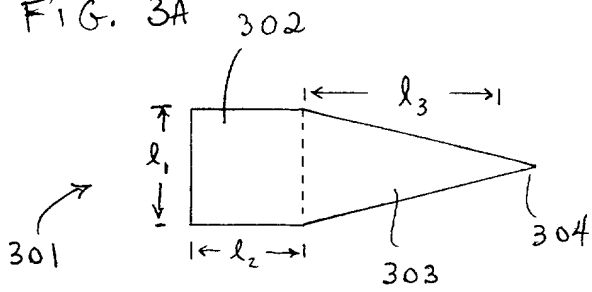


FIG. 3B

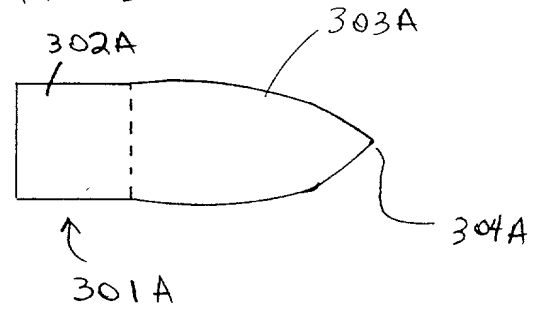


FIG. 4

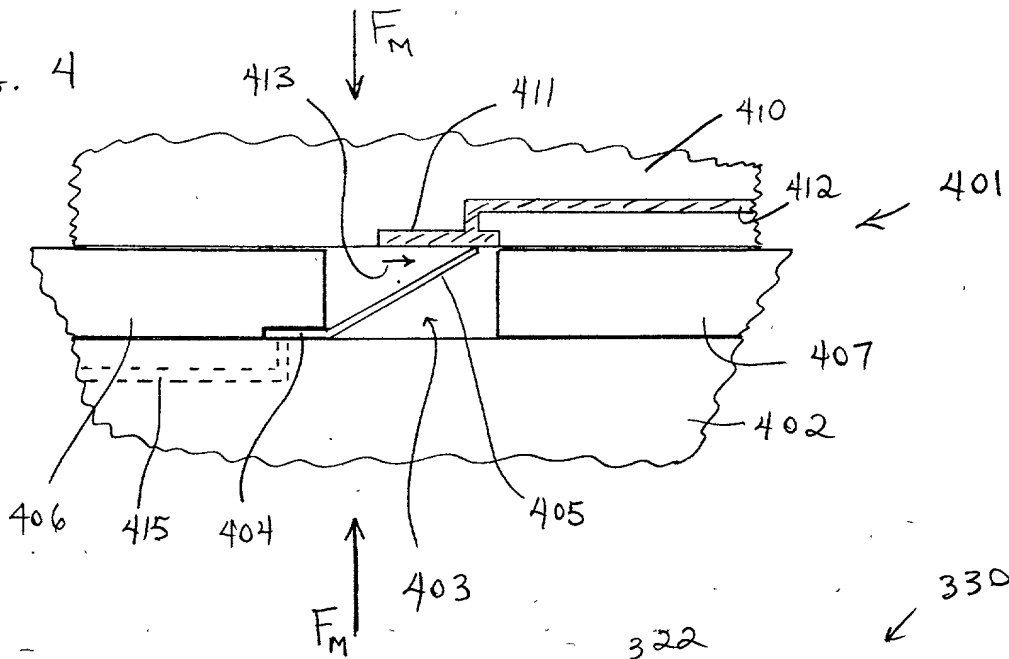


FIG. 3C

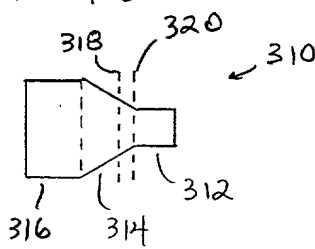


FIG. 3D

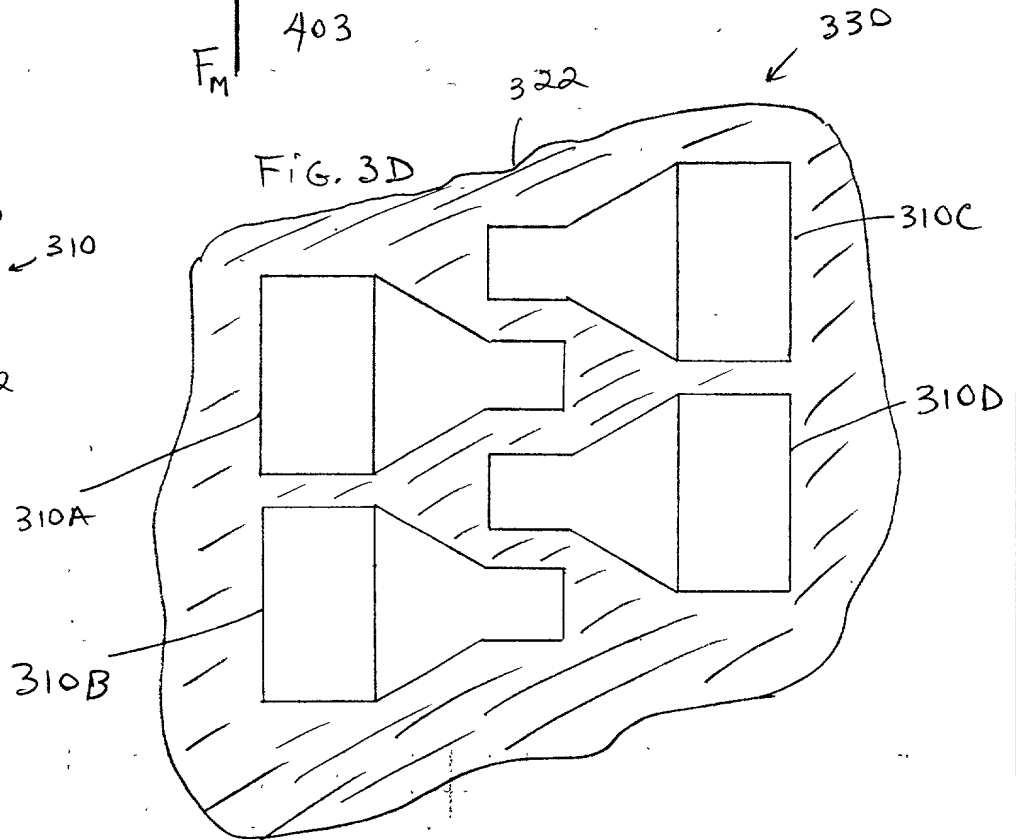


Fig. 5

500

Apply passivation layer (e.g. spin-on polyimide layer) and pattern passivation layer to expose contact pads

502

Apply (e.g. sputter) shorting layer & apply photoresist and pattern photoresist

504

Apply (e.g. electrolytically plate) redistribution layer and strip photoresist and strip shorting layer (using redistribution layer as a mask)

506

Apply photoresist and pattern photoresist to include an opening having a slope on the photoresist

508

Apply (e.g. sputter) seed layer and apply and pattern photoresist to create triangular opening for resilient contact element

510

Apply (e.g. electrolytically plate) first and second metal layers into triangular opening (second metal may be optional)

512

Strip Photoresist layers and strip seed and sputtered layers ;

514

Apply, Expose and Develop photoresist (e.g. a negative photoresist such as SU8) to create a stop structure on the base of resilient contact element(s)

516

FIG. 6A

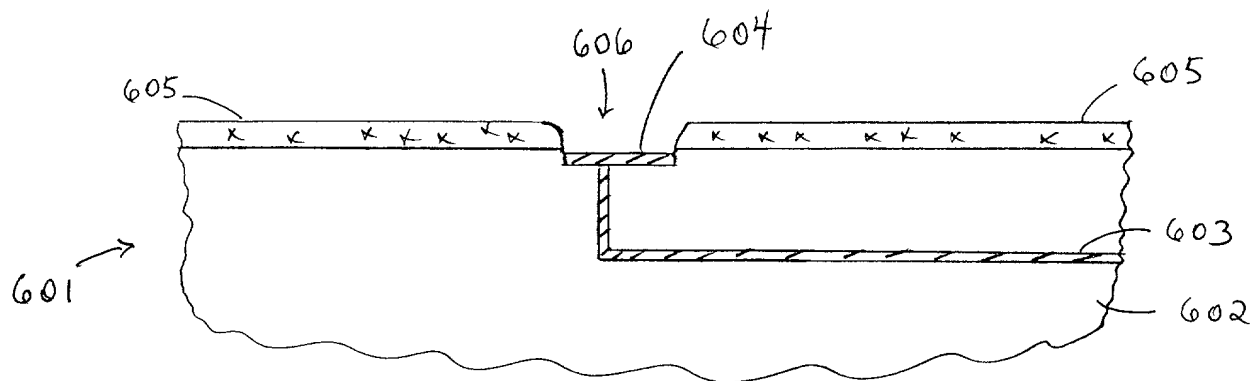


FIG. 6B

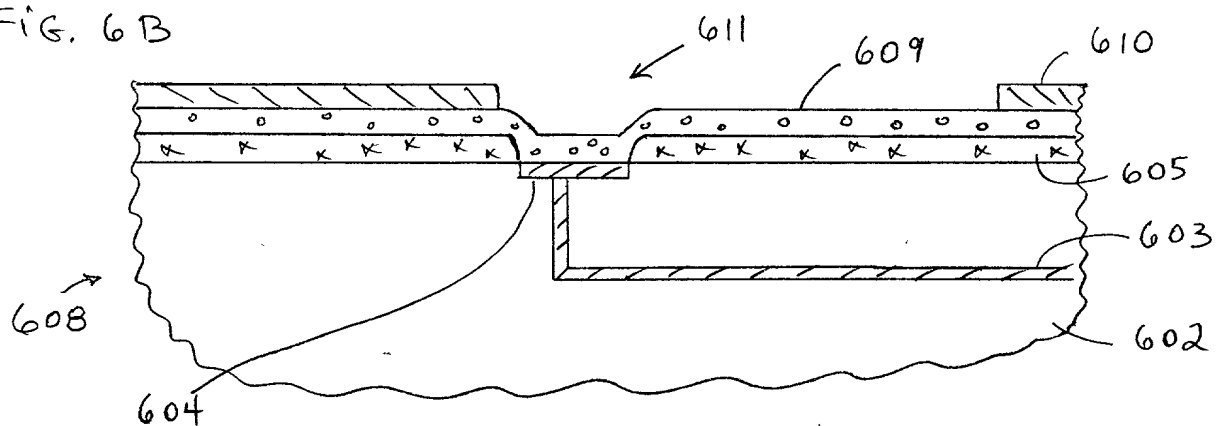


FIG. 6C

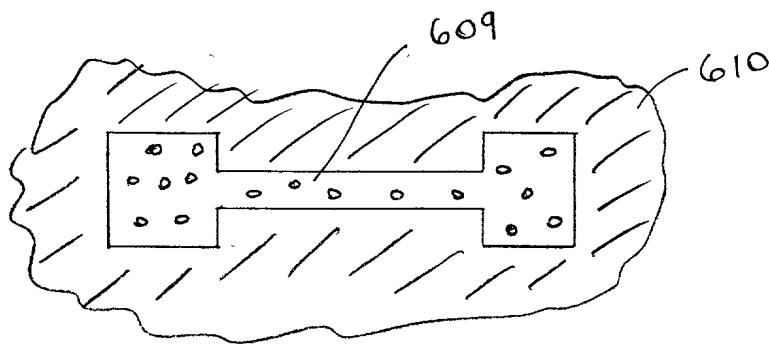


FIG. 6D

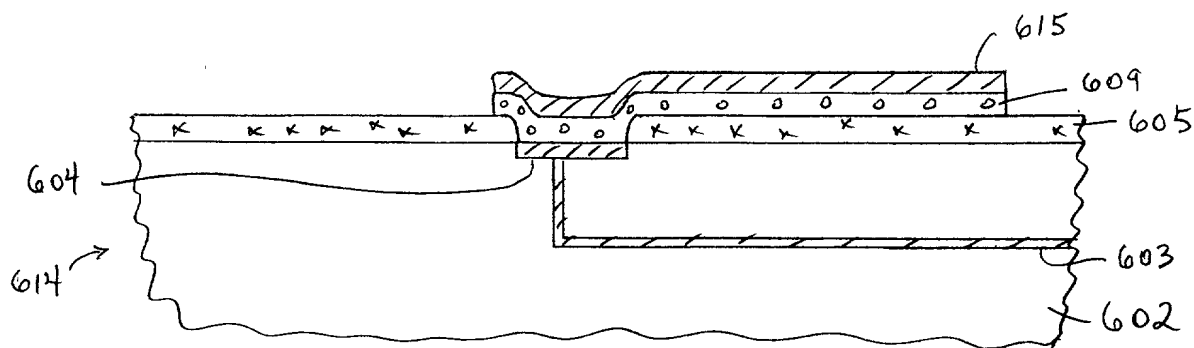


FIG. 6E

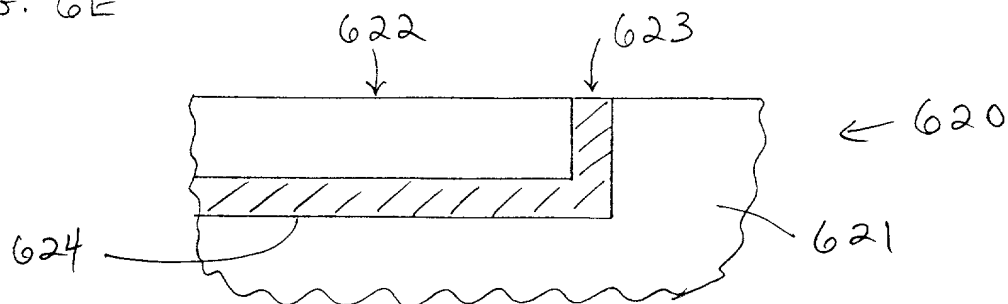


FIG. 6F

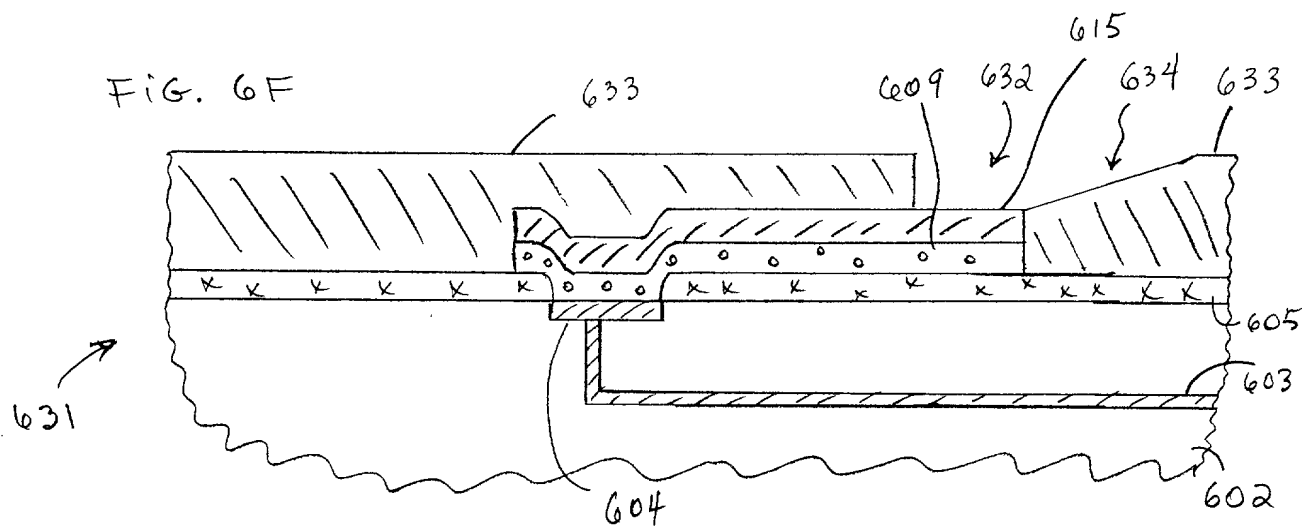


Fig. 6G

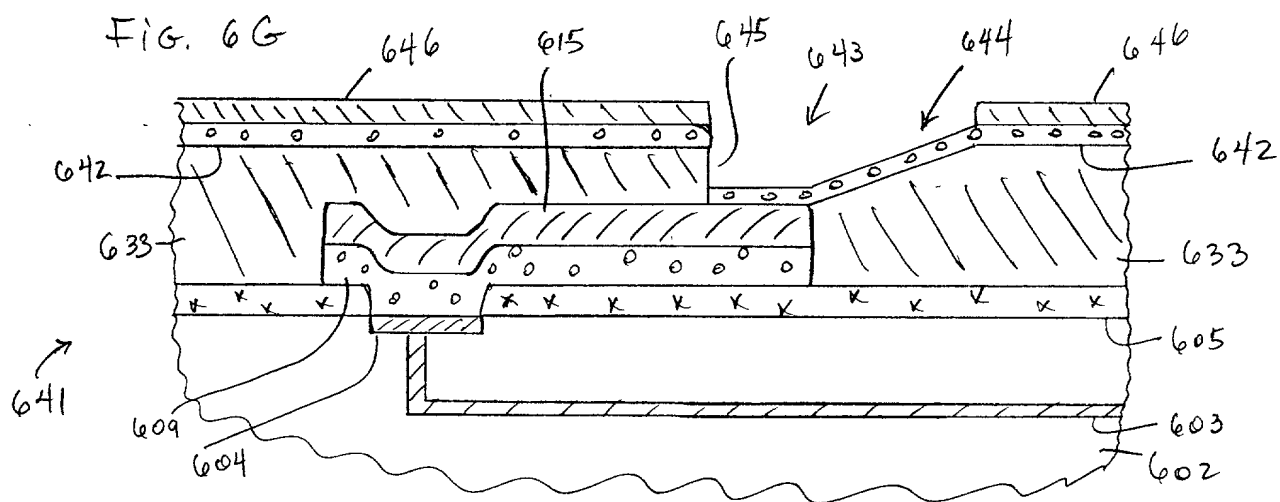


FIG. 6H

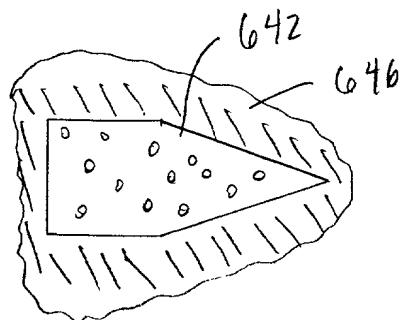




FIG. 6I

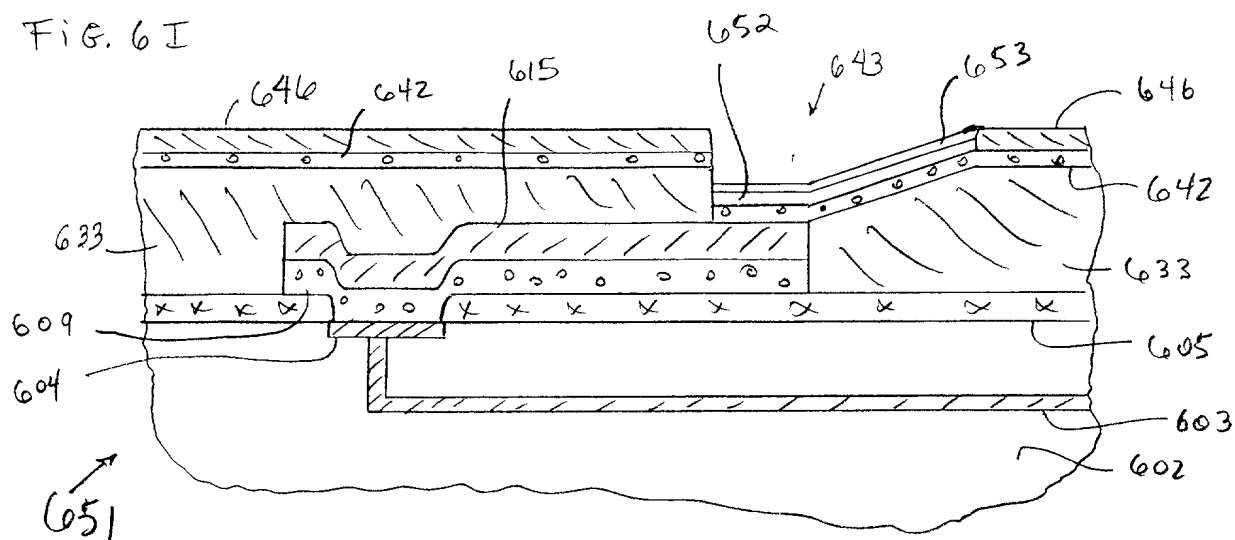


FIG. 6J

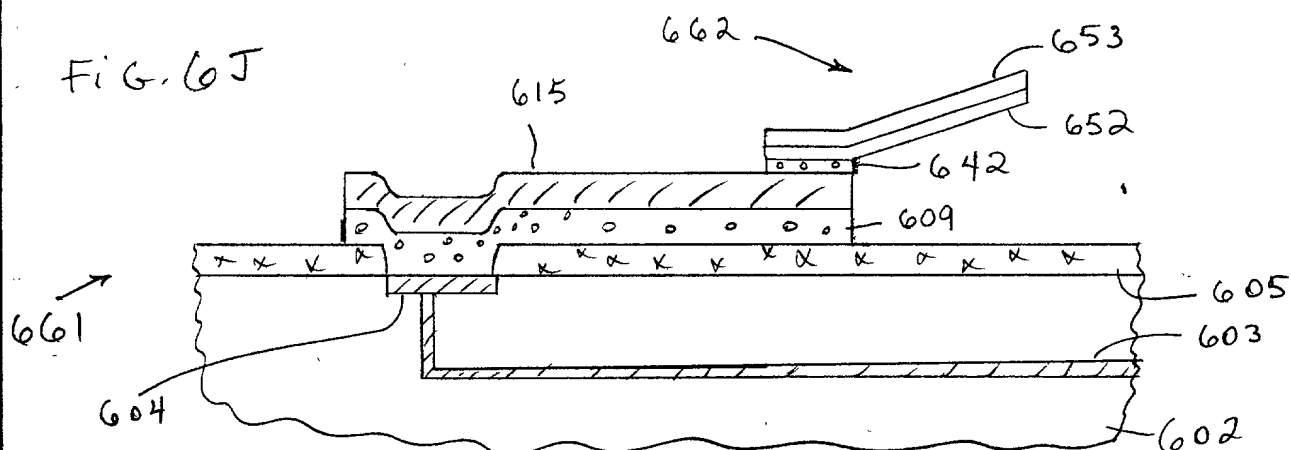


FIG. 6K

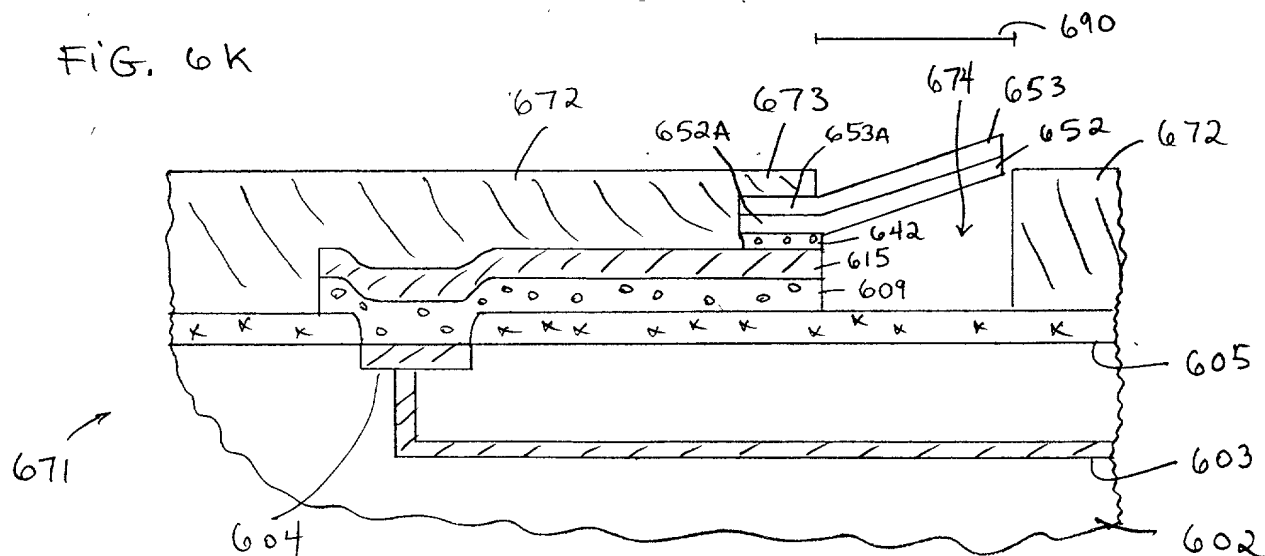


FIG. 6L

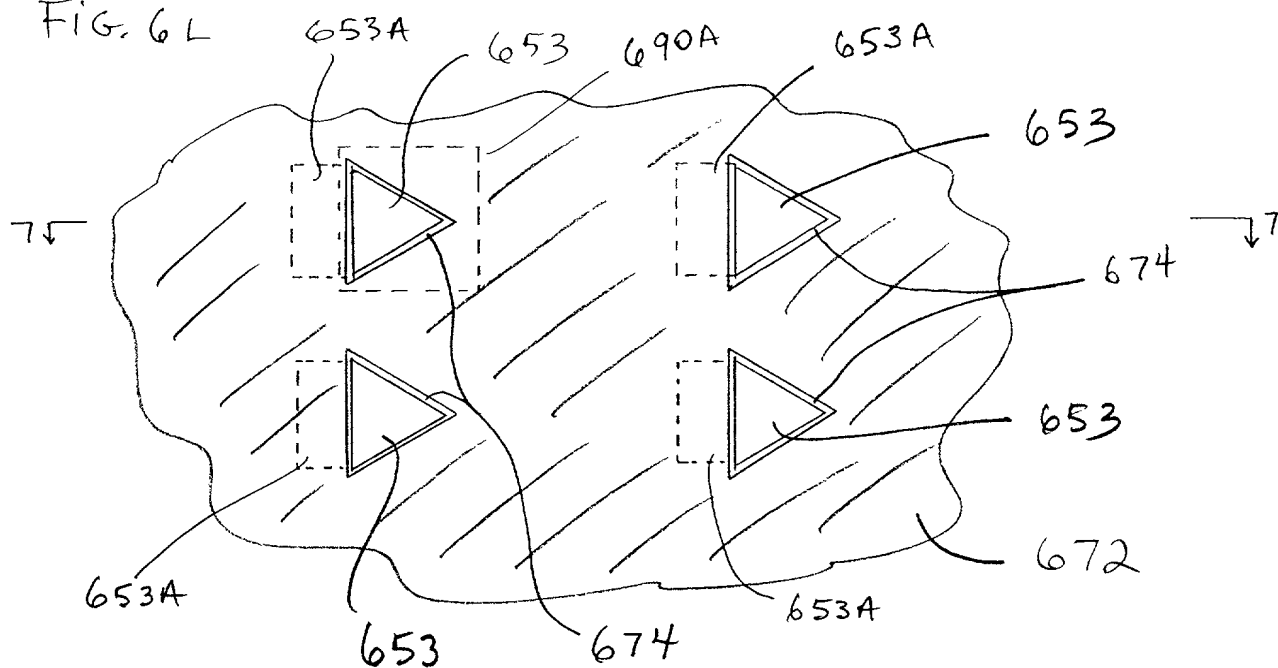


FIG. 7A

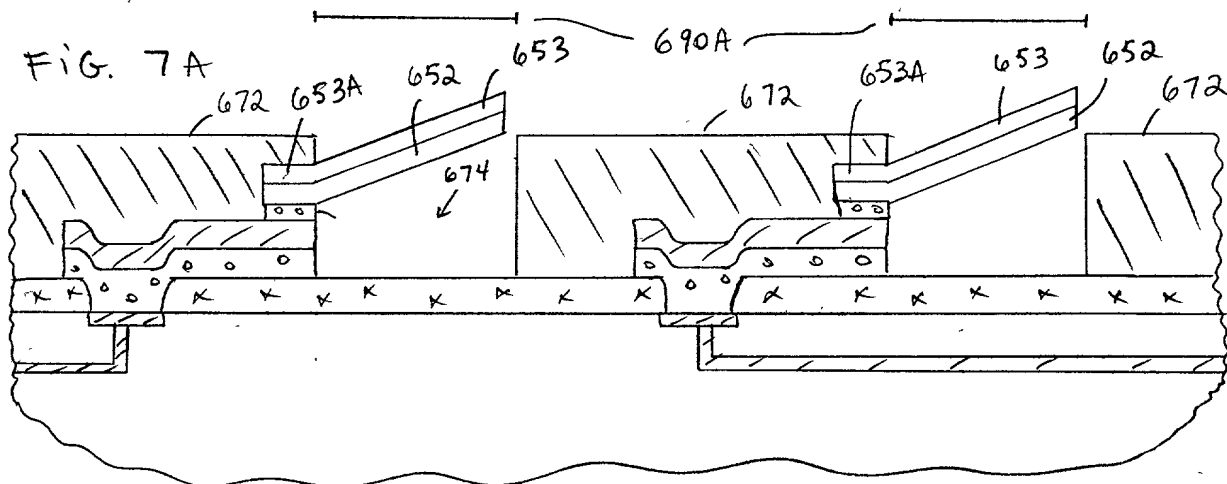


FIG. 7B

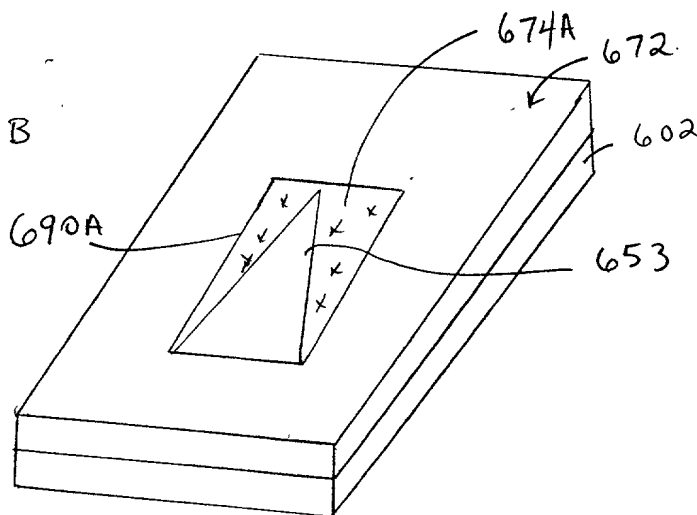




FIG. 8A

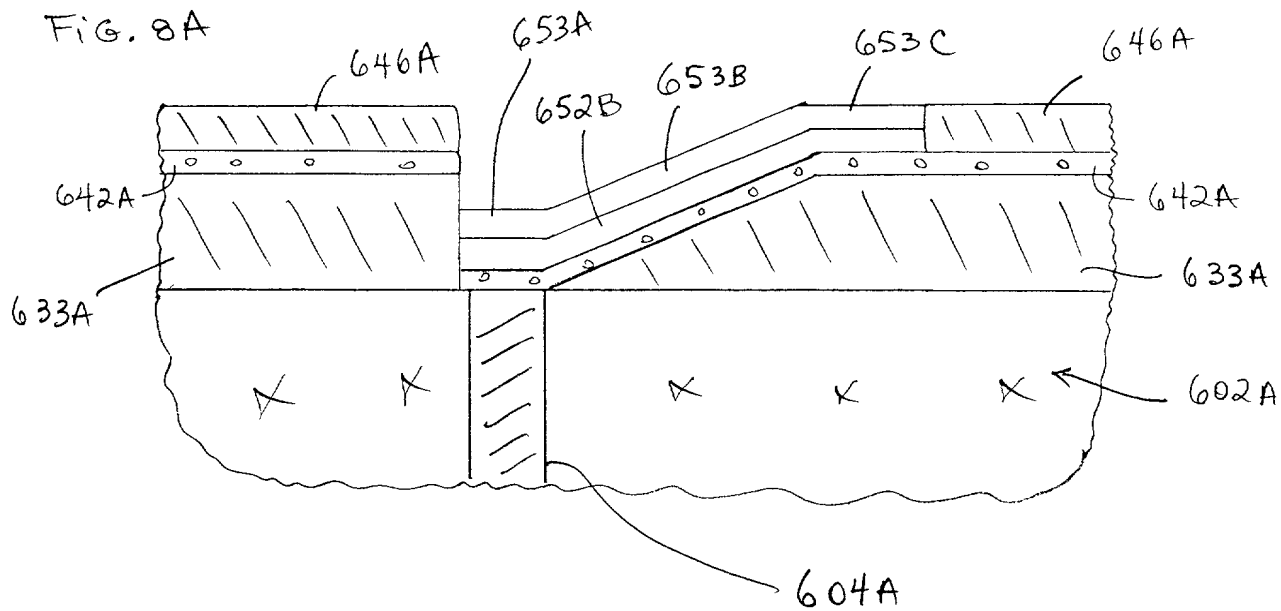


FIG. 8B

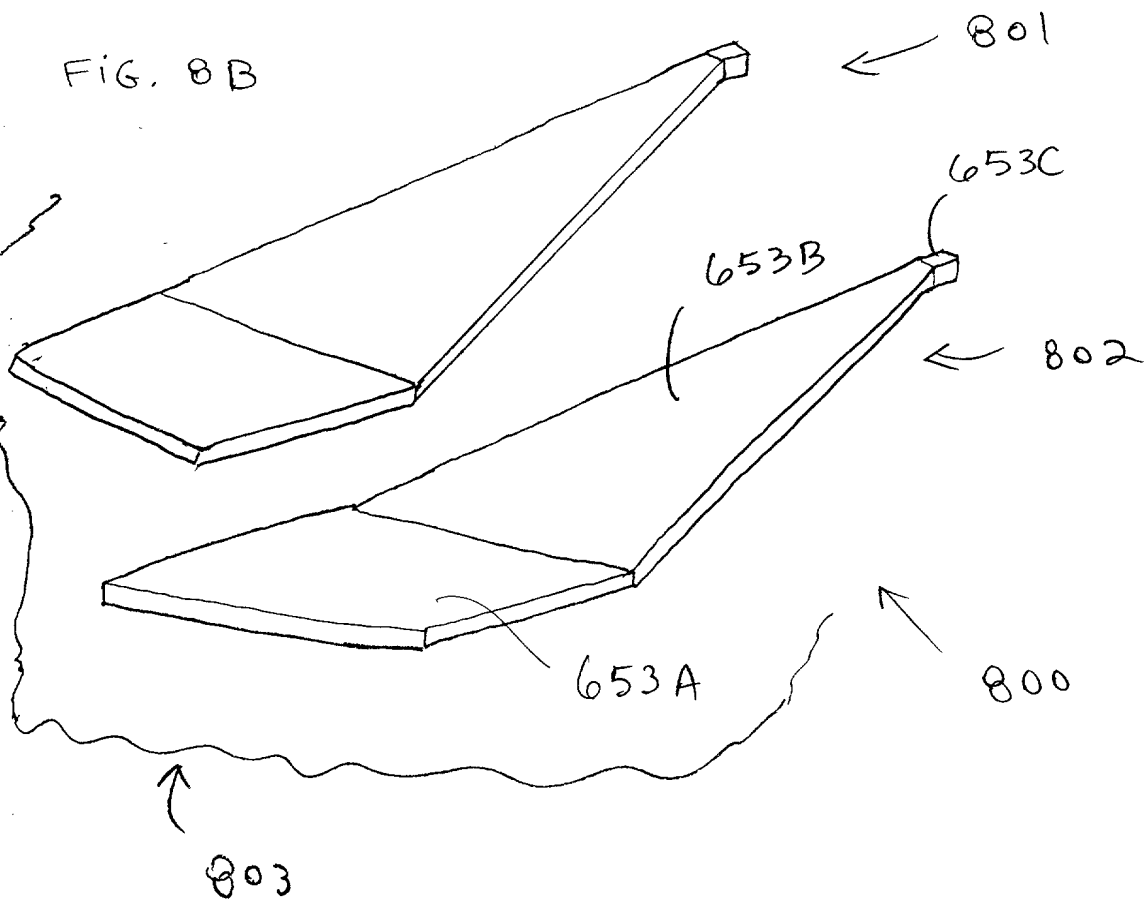


FIG. 9A

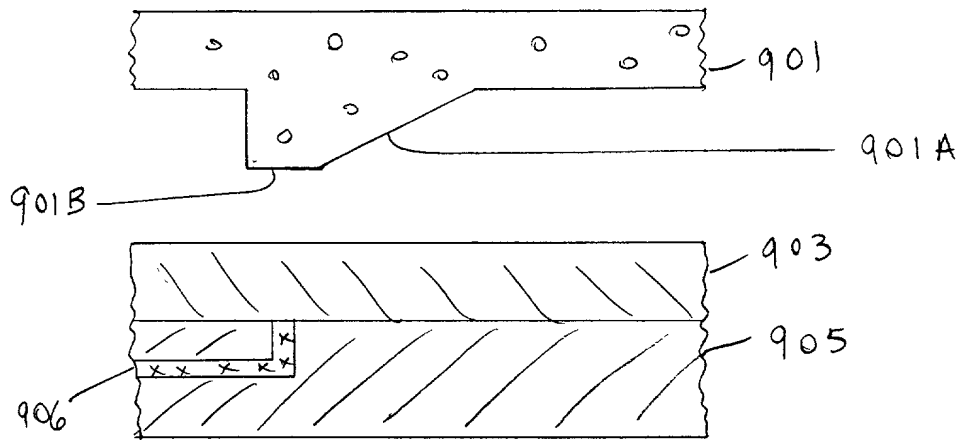


FIG. 9B

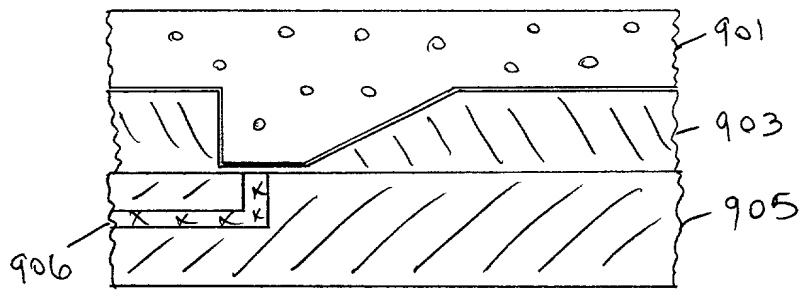


FIG. 9C

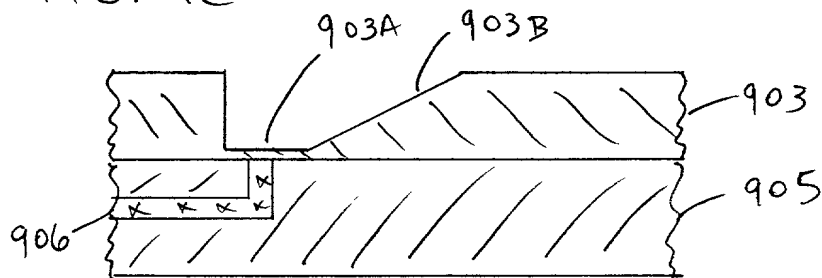
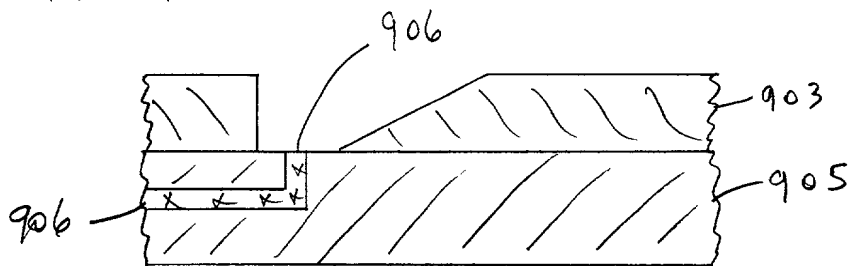


FIG. 9D



DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below, next to my name.

I believe I am the original, first, and sole inventor (if only one name is listed below) or an original, first, and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

INTERCONNECT ASSEMBLIES AND METHODS

the specification of which

 X is attached hereto.
 was filed on _____ as
United States Application Number _____
or PCT International Application Number _____
and was amended on _____
(if applicable)

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claim(s), as amended by any amendment referred to above. I do not know and do not believe that the claimed invention was ever known or used in the United States of America before my invention thereof, or patented or described in any printed publication in any country before my invention thereof or more than one year prior to this application, that the same was not in public use or on sale in the United States of America more than one year prior to this application, and that the invention has not been patented or made the subject of an inventor's certificate issued before the date of this application in any country foreign to the United States of America on an application filed by me or my legal representatives or assigns more than twelve months (for a utility patent application) or six months (for a design patent application) prior to this application.

I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d), of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)

Priority
Claimed

_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	Yes	No
_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	Yes	No

I hereby claim the benefit under title 35, United States Code, Section 119(e) of any United States provisional application(s) listed below

_____ (Application Number)	_____ Filing Date
_____ (Application Number)	_____ Filing Date

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

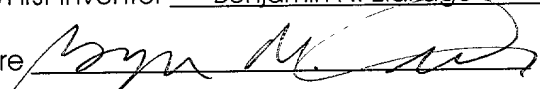
_____ (Application Number)	_____ Filing Date	_____ (Status -- patented, pending, abandoned)
_____ (Application Number)	_____ Filing Date	_____ (Status -- patented, pending, abandoned)

I hereby appoint the persons listed on Appendix A hereto (which is incorporated by reference and a part of this document) as my respective patent attorneys and patent agents, with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected herewith.

Send correspondence to James C. Scheller, Jr., BLAKELY, SOKOLOFF, TAYLOR &
(Name of Attorney or Agent)
ZAFMAN LLP, 12400 Wilshire Boulevard 7th Floor, Los Angeles, California 90025 and direct
telephone calls to James C. Scheller, Jr., (408) 720-8598.
(Name of Attorney or Agent)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

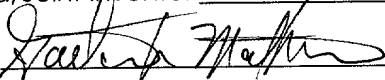
Full Name of Sole/First Inventor Benjamin N. Eldridge

Inventor's Signature  Date 7/29/99

Residence Danville, California Citizenship United States
(City, State) (Country)

Post Office Address 651 Sheri Lane
Danville, CA 94523

Full Name of Second/Joint Inventor Gaetan Mathieu

Inventor's Signature  Date 7/29/99

Residence Livermore, California Citizenship Canada
(City, State) (Country)

Post Office Address 659 Orange Way
Livermore, CA 94550

APPENDIX A

William E. Alford, Reg. No. 37,764; Farzad E. Amini, Reg. No. P42,261; Aloysius T. C. AuYeung, Reg. No. 35,432; William Thomas Babbitt, Reg. No. 39,591; Carol F. Barry, Reg. No. 41,600; Jordan Michael Becker, Reg. No. 39,602; Bradley J. Bereznek, Reg. No. 33,474; Michael A. Bernadidou, Reg. No. 35,934; Roger W. Blakely, Jr., Reg. No. 25,831; Gregory D. Caldwell, Reg. No. 39,926; Yong S. Choi, Reg. No. P43,324; Thomas M. Coester, Reg. No. 39,637; Michael Anthony DeSanctis, Reg. No. 39,957; Daniel M. De Vos, Reg. No. 37,813; Robert Andrew Diehl, Reg. No. 40,992; Tarek N. Fahmi, Reg. No. 41,402; James Y. Go, Reg. No. 40,621; Dinu Gruia, Reg. No. P42,996; David R. Halvorson, Reg. No. 33,395; Willmore F. Holbrow III, Reg. No. P41,845; George W. Hoover II, Reg. No. 32,992; Eric S. Hyman, Reg. No. 30,139; Dag H. Johansen, Reg. No. 36,172; William W. Kidd, Reg. No. 31,772; Michael J. Mallie, Reg. No. 36,591; Andre L. Marais, under 37 C.F.R. § 10.9(b); Paul A. Mendonsa, Reg. No. 42,879; Darren J. Milliken, Reg. No. 42,004; Thinh V. Nguyen, Reg. No. 42,034; Dennis A. Nicholls, Reg. No. 42,036; Kimberley G. Nobles, Reg. No. 38,255; Daniel E. Ovanezian, Reg. No. 41,236; Babak Redjaian, Reg. No. 42,096; James H. Salter, Reg. No. 35,668; William W. Schaal, Reg. No. 39,018; James C. Scheller, Reg. No. 31,195; Anand Sethuraman, Reg. No. P43,351; Charles E. Shemwell, Reg. No. 40,171; Jeffrey Sam Smith, Reg. No. 39,377; Maria McCormack Sobrino, Reg. No. 31,639; Stanley W. Sokoloff, Reg. No. 25,128; Judith A. Szepesi, Reg. No. 39,393; Vincent P. Tassinari, Reg. No. 42,179; Edwin H. Taylor, Reg. No. 25,129; George G. C. Tseng, Reg. No. 41,355; Joseph A. Twarowski, Reg. No. 42,191; Lester J. Vincent, Reg. No. 31,460; Glenn E. Von Tersch, Reg. No. 41,364; John Patrick Ward, Reg. No. 40,216; Charles T. J. Weigell, Reg. No. 43,398; Kirk D. Williams, Reg. No. 42,229; Steven D. Yates, Reg. No. 42,242; Ben J. Yorks, Reg. No. 33,609; and Norman Zafman, Reg. No. 26,250; my patent attorneys, and James A. Henry, Reg. No. 41,064; my patent agent, of BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN LLP, with offices located at 12400 Wilshire Boulevard, 7th Floor, Los Angeles, California 90025, telephone (310) 207-3800, and James R. Thein, Reg. No. 31,710, my patent attorney. I also hereby appoint David Larwood, Reg. No. 33,191, my attorney; of FORMFACTOR, INC., located at 5666 La Ribera Street, Livermore, California, 94550, telephone (510)294-4300, with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected herewith.

APPENDIX B

Title 37, Code of Federal Regulations, Section 1.56 Duty to Disclose Information Material to Patentability

(a) A patent by its very nature is affected with a public interest. The public interest is best served, and the most effective patent examination occurs when, at the time an application is being examined, the Office is aware of and evaluates the teachings of all information material to patentability. Each individual associated with the filing and prosecution of a patent application has a duty of candor and good faith in dealing with the Office, which includes a duty to disclose to the Office all information known to that individual to be material to patentability as defined in this section. The duty to disclose information exists with respect to each pending claim until the claim is cancelled or withdrawn from consideration, or the application becomes abandoned. Information material to the patentability of a claim that is cancelled or withdrawn from consideration need not be submitted if the information is not material to the patentability of any claim remaining under consideration in the application. There is no duty to submit information which is not material to the patentability of any existing claim. The duty to disclose all information known to be material to patentability is deemed to be satisfied if all information known to be material to patentability of any claim issued in a patent was cited by the Office or submitted to the Office in the manner prescribed by §§1.97(b)-(d) and 1.98. However, no patent will be granted on an application in connection with which fraud on the Office was practiced or attempted or the duty of disclosure was violated through bad faith or intentional misconduct. The Office encourages applicants to carefully examine:

- (1) Prior art cited in search reports of a foreign patent office in a counterpart application, and
 - (2) The closest information over which individuals associated with the filing or prosecution of a patent application believe any pending claim patentably defines, to make sure that any material information contained therein is disclosed to the Office.
- (b) Under this section, information is material to patentability when it is not cumulative to information already of record or being made or record in the application, and
- (1) It establishes, by itself or in combination with other information, a prima facie case of unpatentability of a claim; or
 - (2) It refutes, or is inconsistent with, a position the applicant takes in:
 - (i) Opposing an argument of unpatentability relied on by the Office, or
 - (ii) Asserting an argument of patentability.

A prima facie case of unpatentability is established when the information compels a conclusion that a claim is unpatentable under the preponderance of evidence, burden-of-proof standard, giving each term in the claim its broadest reasonable construction consistent with the specification, and before any consideration is given to evidence which may be submitted in an attempt to establish a contrary conclusion of patentability.

(c) Individuals associated with the filing or prosecution of a patent application within the meaning of this section are:

- (1) Each inventor named in the application;
 - (2) Each attorney or agent who prepares or prosecutes the application; and
 - (3) Every other person who is substantively involved in the preparation or prosecution of the application and who is associated with the inventor, with the assignee or with anyone to whom there is an obligation to assign the application.
- (d) Individuals other than the attorney, agent or inventor may comply with this section by disclosing information to the attorney, agent, or inventor.